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### *Examples (note capitalization and punctuation)*

BULLOUGH, W. S. 1960. *Practical invertebrate anatomy*. 2nd ed. London: Macmillan.

FISCHER, P. H. 1948. Données sur la résistance et de la vitalité des mollusques. *Journal de conchyliologie* **88**: 100–140.

FISCHER, P. H., DUVAL, M. & RAFFY, A. 1933. Études sur les échanges respiratoires des littorines. *Archives de zoologie expérimentale et générale* **74**: 627–634.

KOHN, A. J. 1960*a*. Ecological notes on *Conus* (Mollusca: Gastropoda) in the Trincomalee region of Ceylon. *Annals and Magazine of Natural History* (13) **2**: 309–320.

KOHN, A. J. 1960*b*. Spawning behaviour, egg masses and larval development in *Conus* from the Indian Ocean. *Bulletin of the Bingham Oceanographic Collection, Yale University* **17** (4): 1–51.

THIELE, J. 1910. Mollusca. B. Polyplacophora, Gastropoda marina, Bivalvia. In: SCHULTZE, L. *Zoologische und anthropologische Ergebnisse einer Forschungsreise im westlichen und zentralen Süd Afrika ausgeführt in den Jahren 1903–1905* **4** (15). *Denkschriften der medizinisch-naturwissenschaftlichen Gesellschaft zu Jena* **16**: 269–270.



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THE FORAMINIFERA OF THE LATE VALANGINIAN  
TO HAUTERIVIAN (EARLY CRETACEOUS)  
SUNDAYS RIVER FORMATION OF THE  
ALGOA BASIN, EASTERN CAPE PROVINCE,  
SOUTH AFRICA

By

I. K. MCMILLAN



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towards the cost of publication of this paper.*

*'... we set out and took the road to the Ados Drift, on Sundays River. At noon we reached some hovels near the drift, where we found a slave, a Hottentot woman and a few children, got some milk and butter and had a miserable dinner. I had hoped to have gained an opportunity of examining the steep banks of the river but now saw with concern that I could not possibly reach the limestone rocks on the opposite shore. They have many extraneous fossils embedded in them...'*

C. I. LATROBE—Journal entry for 9th April 1815

(Latrobe 1818)

*'I believe it is not generally known that the eastern bank of the Zwart-kop River, together with the banks of the Zondag River, are rich in marine petrifications ...'*

C. H. GRISBROOK 1830

*'... and then having exhausted the time we had allotted to this locality, we proceeded on to the Sunday's River. It was almost dark when we arrived at the base of the cliffs beyond Roe's, and whilst pitching our tent near where the road turns round into the Koegakama Kloof, the dark line of cliffs appeared so inviting that had there been but a moon we should certainly have scaled them at once, tired as we were. Next morning we were up at break of day, and ere I had finished my coffee, a loud hurrah! from the cliffs above me, summoned me with a bound to the spot. My friend Bain had gone off without his coffee and got the start of me. There he stood, half dressed, with a splendid gryphoea incurva in his hand, beckoning us to come. "The cliffs are Liasic then!" we both exclaimed; and now commenced a most exciting scene, gryphoeas, trigonias, ammonites, gervillias, exogyras, nautili, whole and in fragments, were thickly strewn over the sides of the cliff, lying uncovered by the rains of years. Each fresh discovery was announced by a louder shout of triumph.'*

W. G. ATHERSTONE 1856—

Describing a field trip to the Zoetgeneugd Cliffs

(Atherstone 1857)



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## INTRODUCTION

Within the Cape Fold Belt, composed mainly of Palaeozoic (Ordovician to Carboniferous) rocks, are a series of basins containing latest Jurassic to earliest Cretaceous sedimentary sequences. These basins are generally half-graben types, which have been infilled with a variety of continental, marginal marine and continental-shelf sediments (McLachlan & McMillan 1976 and references therein). The Algoa Basin is the largest of those developed onshore, containing a sediment pile up to 4 500 m thick, and it also possesses the most marine sequence.

Offshore, extensive seismic exploration and deep drilling undertaken by SOEKOR (Pty) Ltd have revealed the presence of extensions of the onshore basins, lying beneath the present day Agulhas Bank. The arrangement of the Mesozoic Algoa Basin, both on and off the present coast, is shown in Figure 1. The tectonic history of the offshore Algoa Basin was detailed by Bate & Malan (1992), its Early Cretaceous stratigraphy by McMillan *et al.* (1997), and its petroleum geology and exploration potential by Malan (1993) and Broad & Mills (1993).

The onshore portion of the Algoa Basin is composed of two major depressions: the larger Sundays River Trough and the Uitenhage Trough. The Uitenhage Trough is a typical half-graben, bounded to the north-east by the Coega Fault, an extension of the offshore St Croix Fault system (Doherty 1993). In contrast, the Sundays River Trough is a more complex, faulted depression that lacks clear bounding faults (Hill 1972, 1975; Lock *et al.* 1975: 222). The basin floor in the Uitenhage Trough shallows steadily southwards, away from the Coega Fault, and is not affected by major faulting. In contrast, the basin floor in the Sundays River Trough is fractured by a series of faults trending west-north-west to east-south-east, aligned roughly parallel to the northern margin of the basin. These divide the Sundays River Trough into three compartments: a half-graben north of the Commando Kraal Fault, a central horst (the Addo Nose) plunging to the east, and a more depressed area to the south of the Colchester Fault (Battrick 1974) that shallows southward to the ridge underpinning Coegaskop and the St Croix Island group. Depocentres (maximum thicknesses of preserved sedimentation) occur just to the north of the Commando Kraal Fault (intersected by borehole CK 1/68) and south-west and north-east of the distal end of the Colchester Fault (intersected by borehole AL 1/69). The faulting can be best defined on the basement (Horizon D) surface (see Fig. 2), as the poor quality of the onshore seismic data hinders fine resolution of the faulting at higher stratigraphic levels. None the less, during sedimentation of the Sundays River Formation, differential subsidence rates can be seen to have occurred in the north, centre and south of the Sundays River Trough and the Uitenhage Trough, that, coupled with varying rates and types of sediment input are clearly reflected in differences in foraminifera assemblages across the basin. Offshore, the basin fill of the Sundays River Trough progressively onlaps the upthrown side of the St Croix Fault in a southward direction, until the upper Sundays River Formation unconformably overlies basement (D = 1At1) (see Fig. 2).

Apart from the sliver of Suurberg Group volcanic rocks along the northern rim of the Algoa Basin (Hill 1972, 1975; McLachlan & McMillan 1976; Marsh *et al.* 1979), the





basin is surrounded and underlain mainly by Ordovician–Silurian Table Mountain Group quartzites, Devonian Bokkeveld Group black slates, and Devonian–Carboniferous Witteberg Group black slates and sandstones. Deep boreholes drilled to basement in the Sundays River Trough (AD 1/68, AL 1/69, BR 1/71, CK 1/68, CO 2/70, CO 3/71, KE 1/71, NA 1/69, NA 2/70, NA 3/70, SH 1/74, SM 1/76, SV 1/71, VO 1/71) all bottomed in Bokkeveld slates, whereas those drilled to basement in the Uitenhage Trough all bottomed in Table Mountain quartzites (BT 1/74, ST 1/71, SW 1/08). The Mesozoic sedimentary basin infill consists of early conglomerates, then lacustrine, estuarine and fluvial claystones and sandstones, and finally marine claystones and sandstones.

## STRATIGRAPHY

The earliest records of the fossiliferous nature of the onshore Algoa Basin were provided by Latrobe (1818), who recognized fossils at the Addo Wagon Drift, and by Grisbrook (1830), who noted the presence of shell beds near the mouth of the Swartkops River (Amsterdamhoek) and along the Sundays River (probably Zoetgeneugd). Early palaeontological studies have been summarized by McLachlan & McMillan (1976). Lithostratigraphic studies have divided the sequence into a lower half of up to 2 400 m of minor conglomerates (Enon Conglomerate Formation), non-marine sandstones (Swartkops Sandstone Member) and mainly red and green claystones with sandstones (Kirkwood Formation). Near the base of the last-named is a non-marine to shallow marine green-grey or mostly black claystone, which in the Uitenhage Trough has yielded foraminifera, and is termed the Colchester Shale Member. The upper half of the sequence consists of up to 2 000 m of shallow-marine and shelf claystones and sandstones, usually displaying a coarsening upward cyclicity on a fine scale, termed the Sundays River Formation. The stratigraphic relationship of these lithological units is given in Figure 2, and details and relationships of the various units were discussed by Hill (1972, 1975), Winter (1973, 1979), McLachlan & McMillan (1976, 1979) and Shone (1976*b*, 1978), amongst others. Dingle *et al.* (1983) provided a critical overview.

Of the macrofossil remains in the Sundays River Formation, ammonites have provided the most detailed age information. Ammonite datings support a Late Valanginian age for the Sundays River Formation (Spath 1930; Cooper 1981) but, because available outcrops tend to expose only the lowest levels of the sequence (which are also dated microfaunally as Late Valanginian), it is not clear how much of the Sundays River Formation sequence is actually ammonite-bearing. The trigonoid bivalves have recently been the subject of a monograph by Cooper (1991).

### *The Sundays River–Upper Algoa Boundary*

The upper surface of the Sundays River Formation is marked by an unconformity characterized by extensive erosion. Planation of the Sundays River Formation surface has probably occurred since earliest Barremian times, so that today the most complete sequences are near the basin axis, and progressively less and less is preserved towards the basin margins (Fig. 3). It is for this reason that the Hauterivian interval of the axially sited

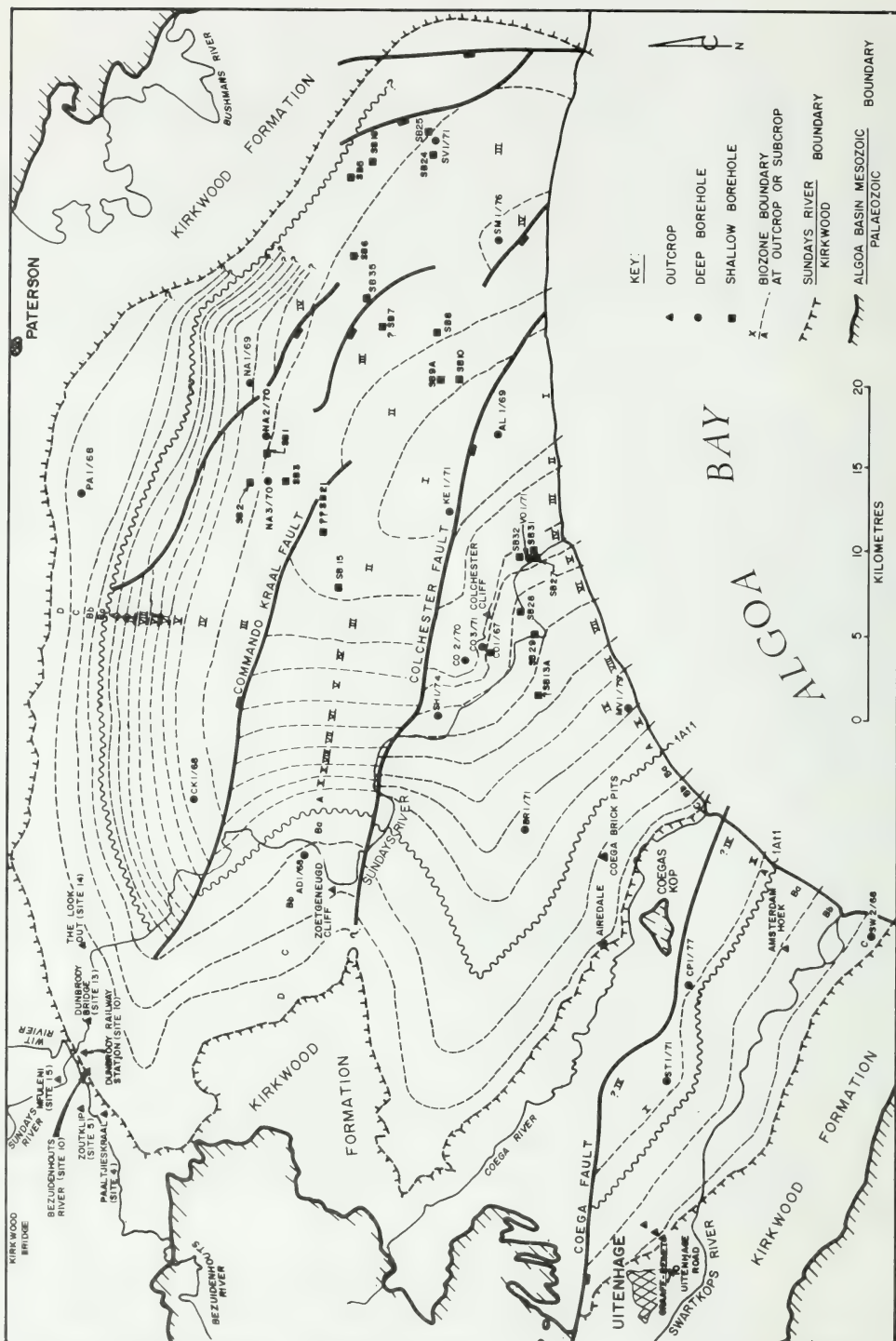


Figure 3.

Outcrop locations and deep and shallow borehole sites in the Sundays River formation with interpreted outcrop/subcrop of foraminifera biozones (defined in the text).



borehole AL 1/69 has been selected for detailed foraminifera study, since it could well be considered a type-section for the upper Sundays River Formation.

Unconformably overlying the Sundays River Formation are the calcarenites and aeolianites of the upper Algoa Group (Pliocene and Pleistocene), together with various alluvial, dune and river terrace accumulations (see McMillan 1990*b*, and references therein). From studies of the onshore and offshore Algoa Basin, and the eastern Cape towards East London, it is clear that marine 'transgressions' inundated the onshore Algoa Basin in Late Campanian–Maastrichtian, earliest Eocene, and Middle Eocene times (lower Algoa Group). Where drilled or studied in outcrop, no trace of the rocks laid down at these times now exists over the Algoa Basin. It is clear that repeated deposition–erosion cycles were responsible for erosion of underlying rock units, including the topmost Sundays River Formation. A similar situation prevailed during the Pliocene and Pleistocene deposition–erosion episodes of the upper Algoa Group. Thus, the present remnant of Sundays River Formation within the onshore Algoa Basin probably reflects rather poorly the original distribution of the Formation. That this is the case is supported by the arrangement of depositional facies over the area of the Sundays River Formation (see Figs 21–24).

Winter (1973) described the Sundays River Formation as consisting of compacted grey clays, silts and sands, which form cyclical sequences (often showing upward coarsening) that are probably due to intermittent subsidence of the basin and consequent fluctuating sedimentary infilling. The surface stratotype of the Sundays River Formation, defined by Winter (1973), is located on and about the farm Zoetgeneugd (modern spelling Soetgenoeg), where high cliffs have been formed by back-cutting by the Sundays River.

#### *The Kirkwood–Sundays River Boundary*

Comments on the nature of this major lithological change have been presented by Winter (1973, 1979) and McLachlan & McMillan (1976). The transition across the boundary in fully-cored borehole CO 1/67 is shown in Figure 4. Earlier (unpublished) reports by Venter (1972*a*, 1972*c*, 1972*d*, 1972*e*) contain a more detailed analysis of the boundary in deep boreholes than has been presented to date in published work. Winter (1973: 26, figs 3*a*, 6) noted that changes in shale specific gravity, reflecting a sudden increase in shale compaction, at the top of the Kirkwood Formation 'not only suggests an unconformity, but also perhaps the very different compaction history of desiccated clays of a red bed sequence, which may also account for the very slow increase with depth'. Thus, the original comments of Winter (1973) are somewhat ambiguous as to whether there is an unconformity at the Kirkwood–Sundays River formational boundary, or not, reflecting the uncertainties previously voiced by Venter on this subject. However, McLachlan & McMillan (1976: 199) again postulated an unconformity on the basis of changes on the shale density graphs and dipmeter logs. Winter (1979: 188) accommodated both options, by stating 'the lower boundary of the (Sundays River Formation) may interfinger with the Kirkwood Formation or be an unconformity'. This perhaps reflects arguments by Shone (1978), who viewed the Kirkwood Formation as grading laterally into the Sundays River Formation. Shone (1978: 325) made additional

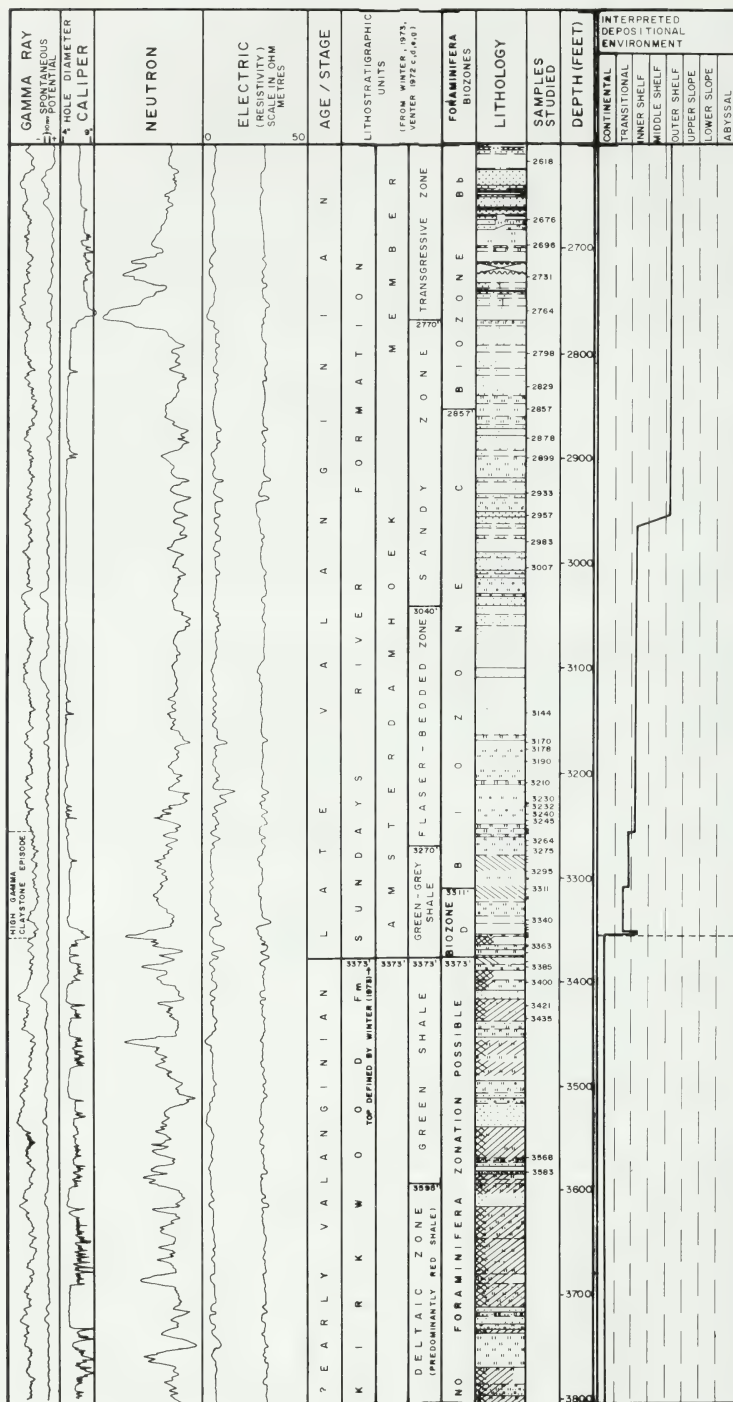


Figure 4.

Boundary between the Kirkwood and Sunday River Formations in cored borehole CO 1/67, showing lithologies, electric logs, defined lithostratigraphic units, interpreted depositional environment from the foraminifera study, and depths of studied samples.



comments on the clay compaction curve presented by Winter (1973, fig. 3a), and disputed the resulting interpretation of an unconformity at the Kirkwood–Sundays River formational boundary. However, Shone (1978) instead suggested an unconformity between the Enon Conglomerate Formation and the Kirkwood Formation, based on the difference in the palaeoslope during Enon times compared with Kirkwood Formation times.

Three outcrop localities have been described that suggest the Kirkwood Formation interfingers with the Sundays River Formation. Rigassi (1968: 9, pl. 23) described such a section at the Airedale brick-clay quarries, noted also by Rigassi & Dixon (1972: 519), but McLachlan (*in* McLachlan & McMillan 1976: 207) found no unequivocal evidence of such a relationship. Secondly, Shone (1976*b*: 17) noted the gradation of facies from Bezuidenhouts River bridge to Dunbrody, but found the precise relationship of the lateral gradation to be unclear. Fossil data from these outcrops shows there to be a steadily increasing marine influence basinwards, although on the fine scale some fluvial red beds and estuarine oyster-bearing grey claystones have been found interbedded west of Blue Cliffs Station (McLachlan & McMillan 1976, fig. 7, site 1). Thirdly, north of Uitenhage, Rogers & Schwarz (1901: 4) identified marine beds outcropping beneath Enon conglomerates, but Haughton (1928) recognized that the conglomerates occurred on the upthrown side of the Coega Fault, and the marine beds on the downthrown side (see also McLachlan & McMillan 1976: 199, fig. 4). Thus there seems to be no clear evidence of major interfingering of the Kirkwood and Sundays River formations in outcrop, as concluded by McLachlan & McMillan (1976).

Venter (1972*a*) utilized well logs, sandstone percentage graphs, rate of penetration while drilling, dipmeter results, shale density logs, calcimetry and clay mineral distributions to establish correlations between boreholes within the Kirkwood and Sundays River formations. Subsequently, Venter (1972*e*) analysed electric logs and lithologies across the Kirkwood–Sundays River formational boundary, with the specific aim of attempting to determine if an unconformity exists at the boundary. He concluded that the well logs display only small peaks that generally are small and lack diagnostic features (see Winter 1973, fig. 2; Winter 1979, fig. 6; herein Fig. 4). None the less, some log markers were established. Sandstone percentage graphs were affected by the ‘shaling-out’ of the formation towards the basin centre, and the presence of many small sandstones and few diagnostic ones, that led to difficulties in confirming correlations from one borehole to the next. Fluctuations of penetration rate seem to be related to the type of environment, with continental section generally drilling at a slower rate than marine section; no clear correlations were obtained using this method alone but it had some value when related to sandstone abundance. Venter (1972*a*) remarked on the abrupt change in dip seen at the top of the Kirkwood Formation on dipmeter logs from all the boreholes he studied. Other, apparently localized changes in dip occur in the lower Sundays River Formation and the upper Kirkwood Formation. As noted previously, shale density graphs show a steeper gradient for the Kirkwood Formation than for the Sundays River Formation. Although some features proved of local correlation value, percentage calcite and percentage dolomite values from calcimetry provided only a poor correlation.

Similarly, little success was gained with correlation using clay mineral compositions. Venter (1972a) concluded that lithological correlation within the onshore Algoa Basin was incomplete and ineffective, and that subdivision was limited to sedimentary cycles that were mainly of a local nature. Despite Venter's (1972e) attempts to correlate green claystone beds and borehole logs above and below the boundary, he was unable to determine if an unconformity occurs at the Kirkwood–Sundays River formational boundary, due to discontinuity of lithologies, and the limited, localized sedimentary cycles evident in the borehole logs. Log correlations by Venter and by subsequent SOEKOR analysts suggested that, over most of the onshore Algoa Basin, the Kirkwood–Sundays River formational boundary is conformable. Comparisons between the interval zonation based on the foraminifera proposed herein, and the most detailed of the log correlations for the lower Sundays River Formation and upper Kirkwood Formation suggests marine conditions developed virtually synchronously across the entire onshore Algoa Basin.

There is no evidence for truncation of topmost Kirkwood Formation beds either in the basin depocentre or towards the margins; nor is there any clear indication of onlap of basal Sundays River Formation beds towards the basin margins or to identifiably proximal localities. Examination of the cored sections available across the Kirkwood–Sundays River formational boundary in the basin centre (borehole CO 1/67) and towards the margins (boreholes AD 1/68 and PA 1/68) suggests there is a relatively rapid gradation in depositional environment from fluvial to hyposaline to near-normal marine over about 100 m of vertical section in all three sections. Similar rates of change of depositional environment also seem to occur in the other cuttings borehole sections, but unfortunately cavings variably obscure the picture.

Comparisons of well log correlations with the foraminifera interval zonation in the lower Sundays River Formation proposed herein suggest an essential concurrence between the two. Both studies were undertaken without knowledge of the other (Venter 1972a and Leith 1975—on the well logs; McMillan 1980 to 1992—on the foraminifera), so that no attempt has been made to effectively merge the two. It can be seen that there are particularly clear differences in the two correlations in the SH 1/74 section, and these differences remain unresolved (Fig. 7). Fewer log markers have been defined in the upper Kirkwood Formation, but these again reflect the same parallel trends seen in the Sundays River Formation.

Detailed examination of the fully-cored CO 1/67 sequence (Figs 4, 81) across the Kirkwood–Sundays River formational boundary indicates that the appearance of normal marine conditions in the northern Algoa Basin over the Kirkwood surface was rather more erratic than previously supposed. Red beds with minor greens range up to 3 416 ft, above which is a greenish interval that is probably non-marine in depositional environment. A short phase of shallow marine conditions at 3 356 ft, marked by abundant agglutinated foraminifera (mostly *Ammobaculites* and *Haplophragmoides*) is followed by an essentially regressive phase (3 350 to 3 311 ft). Environments of this interval are estuarine, sediments are generally greenish-grey in colour and contain *Miliammina latrobei* sp. nov. exclusively. These marine-influenced events (3 356 to 3 311 ft) fall



within an interval of poor high-gamma response (see Fig. 4, and for areal extent, Fig. 9). This is interpreted to indicate a minor episode of tectonic warping, leading to dislocation of river catchment areas and consequent trapping of coarser clastic bed load on land, followed by an abrupt, short-lived increase in subsidence rate. This event is so discontinuous that it clearly cannot be considered a marine condensed section. Between 3 311 and 3 256 ft there is no microfauna and only rare gastropods occur, which may suggest that this portion of the section accumulated in either riverine or estuarine conditions. Above 3 256 ft the first consistent shallow marine assemblages appear and, though very variable at first, become abundant and diverse above 2 957 ft.

The depth of the unconformity postulated by Winter (1973: 26) and McLachlan & McMillan (1976: 199, 206) on the basis of wireline log data does not correspond with the first appearance of marine conditions at 3 356 ft. The compaction break was identified at 3 373 ft (1028 m) (Winter 1973) or 3 368.5 ft (1 027 m) (Winter 1979, figs 4, 6) in CO 1/67, which appears to be just below the highest incontrovertible red claystones. It is evident that this transgressive episode over red beds occurs widely, and can be seen in borehole PB-A1 at 2 467 ft (752 m) in Pletmos Basin (see McLachlan *et al.* 1976*b*) and in the offshore Algoa Basin in borehole Hb-D1 (see Fig. 2). The transgression was probably induced by abrupt tectonic subsidence of the northern rims of these basins. In the southern, offshore Algoa Basin, the Late Jurassic to Early Cretaceous succession is generally marine throughout, and a transgression is not seen, even though depositional environments are rarely deeper than inner shelf, and usually only transitional or marginal marine. However, severe planation on the 6At1 surface has mostly removed beds coeval to the Sundays River Formation (see McMillan *et al.* 1997) in the offshore Algoa Basin. In the clayier, more distal shelf sections seen in the southern Gamtoos Basin, diverse foraminifera faunas occur across the boundary equivalent in time to the base of the Sundays River Formation (identified seismically as horizon J1), but a major change occurs in the species present. Underlying beds dated as Early Valanginian are distinguished by the distinctive informal species 'fat *Lagena* sp.' (see McMillan *et al.* 1997, fig. 3).

In all cases in the present study, the position of the top Kirkwood Formation is placed at the first appearance down-hole of red beds, following Winter's (1973) interpretation, as in Figures 2, 9 and 10.

## PREVIOUS WORK ON FORAMINIFERA OF THE SUNDAYS RIVER FORMATION

### *Early studies*

Earliest work on the foraminifera of the onshore Algoa Basin was undertaken by Union Oil and P. Brönnimann, then with Paleolab. No details are available of these unpublished studies, except for the comments of Rigassi (1968: 14) who, basing his conclusions on this work and additional studies by palaeoconsultants, attempted a foraminifera zonation of the Sundays River Formation into five units. Data were derived essentially from outcrop samples, together with samples from fully-cored borehole CO 1/67, at that time still

AGE	RIGASSI* 1968 FORAMINIFERA	VENTER* 1972a FORAMINIFERA	BEER* 1973 FORAMINIFERA	BRENNER & OERTLI* 1976 OSTRACODA	THIS STUDY* FORAMINIFERA
VALANGINIAN	SECTION NOT SEEN IN CO 1/67	ZONE 1: BARREN ZONE 2: Pseudolamarckina ZONE 1220'	BIOZONE A: UPPER HAUTERIVIAN Lamarckina sp. Frondeularia hexacarinata DIVERSE FAUNAS 1190'	ZONE A: ABUNDANT OSTRACODS 290m	I Reinholdella plattengensis 550' 254'
	ZONE 1: Citharina sparsicostata Citharina harpa Epistominina aff. australiensis + 1100'	ZONE 3: Eoguttulina ZONE 1770'	BIOZONE B: LOWER HAUTERIVIAN Textularia foeda Citharina striatula Vaginulina kochii Vaginulina arguta MAINLY DIVERSE FAUNAS BUT RARE AT TOP 2530'	ZONE B: RARE OSTRACODS 585m	II Upper Epistominina hechti 790' III Amphicoryna pletmosiana 150' IV Pseudopolymorphina colchesterensis 1510'
EARLY VALANGINIAN	ZONE 2: BARREN ZONE WITH VERY RARE AGGLUTINATED FORAMINIFERA AND OSTRACODS	ZONE 4: Ammonobaculites (Hopliphragmium) acculis ZONE 2970'	BIOZONE C: UPPER UPPER VALANGINIAN RELATIVELY POOR FAUNAS WITH FEW DISTINCTIVE SPECIES	ZONE C: ABUNDANT OSTRACODS 800m	V Lower Epistominina hechti 1540' VI Dorothis inglesidensis 1630' VII Vaginulinopsis cf. mutulina 2060' VIII Upper poor zone 2560'
	ZONE 3: SIMILAR TO ZONE 1 BUT POORER 1950'	ZONE 5: INTERZONE (POOR FAUNAS AND RICH IN SANDSTONES) 4520'	BIOZONE D: LOWER UPPER VALANGINIAN ABUNDANT Epistominina caracolla, with Conorboides hofkeri and Conorboides valendisensis 4990'	ZONE D: RARE OSTRACODS	IX Eoguttulina sp. B TOP NOT IDENTIFIED 3990'
LATE VALANGINIAN	ZONE 4: Epistominina aff. australiensis Citharina sparsicostata Citharina cristellarioides Co. cf. hofkeri; M. cf. trochus E. cf. caracolla 2700' OR DEEPER ?? ZONE 5: Epistominina "supracretacea" Epistominina zuluensis Epistominina aff. rpleyensis "NOT YET FOUND IN CO 1/67"	ZONE 6: Epistominina caracolla ZONE with Conorboides hofkeri and Conorboides valendisensis 4990'	ALL FAUNAS CONSIDERED CAVED HERE 5420'	ZONE E: ABUNDANT OSTRACODS 1370m Cytherella algoensis 1480m Cytherella coegaensis 1535m Cytherella schwarzi 1625m Base Cytherella algoensis	X Dorothis australis TOP NOT IDENTIFIED 3990' A Reinholdella hofkeri Reinholdella valendisensis 4560' B Lenticulina coegaensis 4950' Bb Sculpobaculites goodlandensis 5360' C Lower poor zone TOP NOT IDENTIFIED D Miliammina latrobei

\*BASED ON AL 1/69.

\*BASED ON AL 1/69.

\*BASED ON AL 1/69.

\*BASED ON MAYNC, 1970;

ROVEDA, 1970;

CHURCH ET AL., 1970;

BAGNALL ET AL., 1972c;

ALL ON AL 1/69.

M: Marssonella E: Epistominina

C: Citharina

Co: Conorboides

C: Citharina

Figure 5.

Comparison of biozonation schemes for the Sundays River Formation utilizing foraminifera and ostracods. Data from Rigassi (1968), Venter (1971, 1972b), Bagnall *et al.* (1972c), Beer (1973), and Brenner & Oertli (1976) with Valicenti & Stephens (1984).



drilling. This zonation relied heavily on the Late Cretaceous *Epistomina* zonation established in Zululand by Smitter (1957), but its use for the Early Cretaceous rocks is erroneous. Although some of the foraminifera names employed by Rigassi (1968) have persisted, in general terms his zonation has proved to be unworkable. The age of the Sundays River Formation at this time was considered to range between Valanginian and Aptian–Cenomanian. However, two years later, Rigassi (1970: 18) reported that foraminifera, ostracod, bivalve and cephalopod assemblages from the CO 1/67 borehole indicated a Valanginian to Early Hauterivian age, but no further comments were made on foraminifera zonation schemes.

At about the same time, H. M. Beer (February 1968) and E. M. Beer (December 1968) reported first on proposals, and secondly on results of surface sampling from the Sundays River Formation. Some 162 samples were examined, most of which were derived from outcrops in the Sundays, Coega and Swartkops River valleys, together with a number from the Nanaga area. Foraminifera faunas recovered consisted essentially of agglutinated forms, and notable species recognized included *Ammobaculites aequale* (Roemer) and *Astacolus gibber* Espitalié & Sigal.

Between 1967 and 1971 the majority of the deep drilling of the onshore Algoa Basin was undertaken, and a much clearer picture of the Sundays River Formation and its foraminifera emerged. Unpublished reports on the micropalaeontology of most of these boreholes were available to the author and provided a foundation for this study: CO 1/67 (Maync 1969*b*); CK 1/68 (Maync 1969*a*); AL 1/69 (Maync 1970); AL 1/69 and CO 1/67 (Church *et al.* 1970); AL 1/69 (Roveda 1970); CO 1/67 and AD 1/68 (E. M. Beer 1970); CO 2/70 (Bagnall *et al.* 1971*a*); NA 2/70 (Church *et al.* 1971); ST 1/71 (Bagnall *et al.* 1971*b*); BR 1/71 (Bagnall *et al.* 1971*c*); AD 1/68, CO 1/67, CO 2/70, AL 1/69 (H. M. Beer 1971); KE 1/71 (Bagnall *et al.* 1971*d*); SV 1/71 (Bagnall *et al.* 1971*e*); CO 1/67 (Bagnall *et al.* 1971*f*); VO 1/71 (Bagnall *et al.* 1972*a*); CO 3/71 (Bagnall *et al.* 1972*b*); NA 3/70 (Church *et al.* 1972); and CO 1/67, CO 2/70, CO 3/71, AD 1/68, AL 1/69, VO 1/71 and KE 1/71 (E. M. Beer 1973). However, only the reports by E. M. Beer (1970) and Rigassi (1970) contain illustrations of a few identified species. Compilations of these data have been undertaken by Venter (1971, 1972*b*), H. M. Beer (1971) and Bagnall *et al.* (1972*c*). Summaries of the various early biozonations proposed are shown in Figure 5.

The compilation work of Bagnall *et al.* (1972*c*) concluded that microfaunas of the Sundays River Formation were not varied enough to allow for biozonation. Attempts were made to correlate abundance peaks of particular foraminifera species or groups (calcareous/agglutinated ratios in particular), and of types of macrofaunal debris, with some success. Eight biozones were recognized, based on relative occurrences of foraminifera, and on calcareous/agglutinated ratios. Using borehole sections KE 1/71 and CO 2/70 as 'type-sections', Bagnall *et al.* (1972*c*), from a study of all the microfaunal data, recognized four periods of open marine conditions interspersed with four periods of restricted marine conditions within the Sundays River Formation. They were able to identify all eight biozones only in the depocentre of the basin (AL 1/69 area), but were unsure of the extent of the later biozones towards the basin margins. The most distinctive biostratigraphic horizon recognized at this time was based on the first down-hole

appearance of the ostracod *Cytherella* sp. 1 or *Cytherella* 'oblique' (later formally named *C. algoaensis* by Brenner & Oertli (1976)), but no age implication was yet possible from this horizon.

In their attempts to obtain an age for the Sundays River Formation, Bagnall *et al.* (1972c) noted that comparison with European foraminifera faunas tends to indicate a Neocomian age. Comparison with foraminifera from the Majunga Basin, Madagascar (Espitalié & Sigal 1963) indicates rather a Portlandian to Valanginian age. In this regard, particular mention was made of the species *Astacolus microdictyotos* Espitalié & Sigal, which ranges from Portlandian to Valanginian in the Majunga Basin and occurs through most of the Sundays River Formation. A Neocomian age was concluded, with a possibility of Valanginian alone; however, Bagnall *et al.* (1972c) felt that a Late Jurassic age could not be entirely ruled out.

Venter (1971, 1972b) subdivided the Sundays River Formation into seven biozones, based on foraminifera identified in the various reports completed to that time. These foraminifera biozones show some similarity to those of the Bagnall *et al.* (1972c) study, but several aspects of his correlation are now evidently anomalous. All biozones were recognized in all but the most marginal holes (AD 1/68, BR 1/71). Of particular note was the apparent overstep of biozone 3 on to biozone 5 (numbered from the top), and the wedging out of biozone 4 in the BR 1/71 area and, to a partial degree, in the VO 1/71 area.

In contrast, H. M. Beer (1971), studying the results of four boreholes, recognized four sedimentary cycles within the Sundays River Formation that were associated with particular foraminifera and ostracod species. All four cycles occur in the basin axis (AL 1/69), with a progressive loss of the upper-most cycle 4 and condensing of lower cycles 1 and 2 towards the basin margin (AD 1/68).

E. M. Beer (1973) identified four foraminifera biozones, the older two of which were considered Late Valanginian in age, and the younger two as Hauterivian. The Valanginian-Hauterivian boundary identified by E. M. Beer is markedly higher in the sequence than the *Cytherella algoaensis* horizon subsequently utilized to mark the boundary by Brenner & Oertli (1976). Of the four biozones, the basin margin borehole AD 1/68 intersected only the lowest biozone D, whereas the basin axis holes AL 1/69, KE 1/71 and CO 2/70 intersected all four. The present study is in general agreement with this interpretation. E. M. Beer (1973) made no comments on the implications of an erosive upper surface to the Sundays River Formation.

Other microfaunal work on the Sundays River Formation has concentrated on the taxonomy of the ostracod assemblages, different aspects of which have been examined by Dingle (1969) and Valicenti & Stephens (1984), working on outcrop material, and Brenner & Oertli (1976), who concentrated on the deep borehole sections. An analysis of the foraminifera species of a single clay sample from Coega Brick Pits was reported by Meiring (1973). Palynological studies have been undertaken by Scott (1971, 1976) on northern borehole CK 1/68, but the majority of palynological work on other boreholes remains in unpublished reports of SOEKOR.

Ostracod research has tended to concentrate on the taxonomy of the assemblages: age-dating has been rather imprecise. Brenner & Oertli (1976: 477) concluded that the



sequence was of Valanginian and Hauterivian age. They proposed that the ostracod *Cytherella algoaensis* be utilized as a marker for the Valanginian–Hauterivian boundary, based on its first down-hole appearance (local extinction point). Work from foraminifera studies tends to confirm this subdivision of the Sundays River Formation, if *Reinholdella valendisensis* (Bartenstein & Brand) and *Reinholdella hofkeri* (Bartenstein & Brand) can be considered reliable down-hole markers for the top of the Valanginian.

#### *Later work*

Later foraminifera work has concentrated on other South African outcrops and borehole sections of the same age as the Sundays River Formation. McLachlan *et al.* (1976b) detailed the microfaunas (foraminifera and ostracods) of the Brenton Formation at its outcrop along the banks of Knysna Lagoon, and of the nearby offshore borehole PB–A1: forty-four foraminifera species, one new, were recognized in rocks equivalent in age to the Sundays River Formation. Subsequently, both the Brenton and PB–A1 material has been extensively re-examined, and a much larger number of species is now known from the Brenton outcrop in particular. Furthermore, it has proved possible to recognize much the same foraminifera biozonation in the PB–A1 section as that described herein for the Sundays River Formation, and a correlation of the two sequences, with Brenton and Mngazana, is now possible (see Fig. 8). Revisions of the Brenton and PB–A1 article, together with some additions, are included herein under the relevant foraminifera species in the systematic section. Additional work on the Brenton Formation foraminifera has been detailed by E. M. Beer (1972) and Stapleton & E. M. Beer (1977).

The Brenton Formation was regarded as Late Valanginian in age, equivalent to the oldest part of the ‘Sundays River Formation’ in PB–A1 and of the true Sundays River Formation in the northern Algoa Basin, a correlation that is still regarded as correct. McLachlan *et al.* (1976b: 348) noted that the seismic horizon ‘C’ (now 1At1 unconformity) was originally considered to lie at the top of the lower sandy portion of the Sundays River Formation equivalent in PB–A1. Despite their suggestion that 1At1 was more likely present at the top of the Sundays River Formation equivalent in PB–A1, it is now clear, from both improved seismic and microfaunal data, that the 1At1 unconformity does in fact lie at the top of the sands at 480 m below K.B., and thus *within* the Sundays River Formation equivalent. Further offshore in Pletmos Basin, as at the Ga–A boreholes, 1At1 is compounded with 6At1 and the upper Sundays River Formation equivalent, of latest Valanginian and Hauterivian age, is missing.

In the northern Algoa Basin, the stratigraphic horizon of 1At1 can be located using foraminifera, but its exact seismic position cannot be determined. Both seismic sections and electric borehole logs from this onshore area have been of rather poor and variable quality. By comparison with PB–A1 and other offshore borehole sections, the 1At1 unconformity must lie almost at the top of the *Lenticulina coegaensis* sp. nov. biozone (Late Valanginian biozone Ba). A slight lithological change can be seen here, with clayier sediments below and sandier sediments above, but the change is not a consistent one.

The second rock succession studied for its microfauna, and of similar age to the Sundays River Formation has been the Mngazana Formation of the Transkei coast

(McLachlan *et al.* 1976a). Sediments from two half-grabens, the Mngazana and Mbotyi basins, were studied but the latter yielded only plant debris. The sediments at Mngazana consist of conglomerates, lignitic sandstones, mudstones and occasional limestone lenses, but nevertheless, 32 species of foraminifera were obtained. The foraminifera indicate a Late Valanginian (Biozone B) age, slightly later than that of Brenton. The chronostratigraphic position given for the Mngazana foraminifera assemblage on Figure 8 is the oldest possible position: the latest position possible is immediately above the 1At1 unconformity, that is, within the range of the *Lenticulina coegaensis* sp. nov. biozone.

Subsequent unpublished work on Mngazana samples has shown that Radiolaria are very much more abundant than first thought, particularly in the calcareous samples. Most common are spherical Radiolaria, but dictyomitrid types, and four- and five-armed cross morphotypes also occur. The specimen originally postulated by McLachlan *et al.* (1976a) as algal (*Incertae sedis* A, fig. 18 (no. 23)) is almost certainly referable to the radiolarian genus *Praeconocaryomma*. Similar forms occur in the Hauterivian to Barremian Radiolaria assemblage detailed by Bouysse *et al.* (1983) from the West Indies. In some of the Mngazana samples, Radiolaria are more common than either foraminifera or ostracods. One notable foraminifera to have come from the subsequent re-examination of Mngazana material is *Astacolus microdictyotos* Espitalié & Sigal.

## BOREHOLE AND OUTCROP MATERIAL

### *Deep boreholes*

The locations of boreholes and outcrops studied are shown in Figure 3. Table 1 gives location details of deep boreholes. All depths given in this study are depths below Kelly bushing, sited some 6 or 7 m above ground level on the drilling platform. All 17 rotary boreholes were examined over a 10-m interval, using cuttings samples. Fully-cored borehole CO 1/67 was examined for the most part also at about 10 m (30 ft) interval, although AD 1/68, PA 1/68 and some sections of CO 1/67, especially the Kirkwood–Sundays River transition, were studied at 6-m (20 ft) or 3-m (10 ft) intervals, or even less. In some of the rotary holes, short cores had been cut in the Sundays River Formation: BR 1/71 (1 core), MV 1/79 (2 cores), AL 1/69 (8 cores), SM 1/76 (1 core), SV 1/71 (1 core), NA 1/69 (6 cores) and CK 1/68 (5 cores). Two of the later boreholes (NA 3/70, SM 1/76) recovered runs of side-wall cores, some of which also provide, as do the normal cores, much *in situ* information. This has been related to the results obtained from cuttings samples, the latter variably subject to down-hole caving, in order to optimally interpret the stratigraphic ranges of the foraminifera species encountered. Complete sets of cuttings, with cores of all the deep boreholes drilled to date in the onshore Algoa Basin, as well as the CO 1/67, AD 1/68 and PA 1/68 continuous cores, are held by the Geological Survey at their Silverton depot in Pretoria. The following numbers of samples were studied during the course of the present work: AD 1/68 (37 samples), AL 1/69 (201), BR 1/71 (61), CK 1/68 (190), CO 1/67 (135), CO 2/70 (92), CO 3/71 (107), CP 1/77 (16), KE 1/71 (113), MV 1/79 (68), NA 1/69 (159), NA 2/70 (129), NA 3/70 (119), PA 1/68 (20), SH 1/74 (99), SM 1/76 (142), ST 1/71 (51), SV 1/71 (155),



SW 1/08 (0), SW 2/68 (7), and VO 1/71 (121), a full total of 2 022 cuttings, core and sidewall core samples.

Two boreholes were drilled for testing logging equipment, in the grounds of former SOEKOR depots. SW 2/68 was drilled adjacent to the south-west side of the former Swartkops sanatorium building (now demolished). Since the original Swartkops borehole is believed to be sited beneath the building, the distance between the two borehole sites is negligible. A comparison of lithology tops, such as top of Kirkwood Formation red beds, shows SW 1/08 and SW 2/68 sections to be virtually identical. Total depth of SW 2/68 is 300 ft (91.5 m). Further north, CP 1/77 was drilled in the Motherwell area: total depth is 150 m. Normal cuttings samples, mostly at a 10 m sampling interval, were available from both holes. Cuttings samples from these two boreholes are held only by SOEKOR at Parow, Cape Town.

TABLE 1  
Localities of deep boreholes studied.

Borehole	Farm	Latitude	Longitude	Height KB. above SL. (m)
AD 1/68	Riverside (Addo Drift)	33°35'06"S	25°39'53"E	28
AL 1/69	Platterug	33°41'15"S	25°56'02"E	87.8
BR 1/71	Brak River Outspan	33°42'16"S	25°41'00"E	90.48
CK 1/68	Commando Kraal	33°51'08"S	25°32'00"E	67
CO 1/67	Colchester	33°41'12"S	25°47'32"E	9
CO 2/70	Ingleside	33°40'13"S	25°47'22"E	104.4
CO 3/71	Vetmaakvlakte	33°40'57"S	25°47'41"E	8.9
CP 1/77	Coegaskop	33°47'14.5"S	25°35'41"E	86
KE 1/71	Kenkelbosch Outspan	33°39'40"S	25°52'15"E	86.71
MV 1/79	The Downs (Melville 308)	33°45'15"S	25°45'33"E	62
NA 1/69	Nanaga	33°33'40"S	25°57'10"E	331
NA 2/70	Moria	33°34'12"S	25°55'22.5"E	205.22
NA 3/70	Buffelshoek	33°34'15"S	25°53'30"E	186.83
PA 1/68	Gorah	33°28'22"S	25°53'32"E	307
SH 1/74	Ingleside 215	33°39'12"S	25°45'19"E	9
SM 1/76	Springmount	33°41'17.04"S	26°02'21.85"E	80
ST 1/71	Saltpan	33°46'30"S	25°32'00"E	115.28
SV 1/71	Sea View	33°39'12"S	26°06'06"E	94.2
SW 1/08	Swartkops	33°52'47"S	25°36'43"E	6.1
SW 2/68	Swartkops	33°52'47"S	25°36'43"E	6.1
VO 1/71	Vetmaakvlakte Oos	33°42'10"S	25°50'26"S	6.6

A number of the rotary, cuttings holes are very clean and little affected by down-hole caving: particularly noticeable in this respect are AL 1/69 and MV 1/79. Boreholes CO 2/70, CO 3/71, VO 1/71, and KE 1/71 suffer particularly acutely from down-hole caving. In particular, mud circulation losses in CO 2/70 have led to small, poor quality cuttings samples throughout the interval 274 to 530 m that are clearly not representative: this would seem to be the most affected borehole section of all those studied.

It should be noted that some of the early boreholes (CO 1/67, AD 1/68, PA 1/68, CK 1/68, AL 1/69, NA 1/69) and part of SM 1/76 were originally logged in feet, whereas later holes were logged in metres. For those that were drilled in feet, all bagged cuttings samples and cores, and the lithologs, were marked up in feet. For ease of relocating specific samples and depths, the original imperial measurements have been referred to in this study.

The ostracods from the deep boreholes studied by Brenner & Oertli (1976, table 1) were from two different sets of processing. Most of their material was derived from microfaunal processing by Dr E. M. Beer at the Geological Survey, Pretoria. Subsequent processing (of the three NA boreholes, and PA 1/68, SV 1/71 (Sea View) and SH 1/74) was undertaken at SOEKOR in Johannesburg. Thus, the foraminifera described in the present study are from the same set of samples, and processed in the same manner as those few ostracods detailed by Brenner & Oertli (1976) from the above six boreholes. However, most of their ostracods, from the other 10 holes, can only be related indirectly to the results of the present work, as they originate from a different sample set, often at different depths, and with different processing methods (soaked overnight in water, and sometimes hydrogen peroxide was used for indurated samples—E. M. Beer (1970)).

### *Shallow boreholes*

Between August 1970 and June 1971 over 34 shallow boreholes were drilled through the Pliocene–Pleistocene upper Algoa Group and into the topmost Sundays River Formation. Locations of the boreholes containing cores used in this study are shown in Figure 3. These shallow holes were drilled for geophysical purposes and, in general, no rotary cuttings were collected. However, a substantial number of short cores were cut in the topmost Sundays River Formation, and these have been sampled and processed for microfaunal elements. The 39 samples are very clean, being from cores, and since it has been possible to selectively sample claystone intervals, abundant, well-preserved microfaunas have been found frequently. However, the precise sampling of these cores tended to highlight the same problem seen in attempting to relate the results from cored borehole CO 1/67 with data from adjacent cuttings boreholes. The rotary samples are essentially a mix of lithologies intersected over a 10-m interval, and microfaunas from such samples thus tend to be ‘smoothed’. Core samples, in contrast, yield a microfauna from a discrete 5-cm or thinner interval, so that in the cores from both the deep boreholes and the shallow holes, microfaunas tend to be much more variable from sample to sample than they are in adjacent cuttings holes. The shallow boreholes were logged, and the cores measured out in feet. Samples thus bear imperial depths, for the same reasons as given for the deep non-metric boreholes. These cores are held at the Geological Survey, Silverton, Pretoria.

Because of the short core-sample intervals in the Sundays River Formation, the foraminifera assemblages from the shallow boreholes have proved difficult to date to a precise biozone. In most cases this has been achieved from their geographical position relative to dated tops of the deep boreholes. Table 2 lists the samples and shows their interpreted ages: some data are incomplete or unclear because of deterioration of these

cores since drilling. Because of the shallow depth of burial of the topmost Sundays River Formation, preservation of foraminifera is good, and a number have been illustrated. The top of the Sundays River Formation, at whatever stratigraphic level, tends to yield the best-preserved foraminifera tests, where weathering processes have not been intensive.

TABLE 2  
Samples studied from shallow boreholes.

Borehole no.	Farm	Samples studied depths below K.B.	Base U. Algoa Gp.	T.D. Borehole	Interpreted Biozone
SB 1	Buffelshoek	Core 1: 180' Core 1: 183'6"	127'	184'3	IV
SB 2	Buffelshoek	Core 3: 263'	130'	266'9"	IV
SB 3	Buffelshoek	Core 1: 179'6" Core 3: 206'	130'	213'8"	III
SB 5	Hopewell	Core 1: 176'6" Core 1: 180'	/	181'	?
SB 6	Wicomvale	Core 1: 170'	120'	179'	?III
SB 7	Doornkloof	Core 2: 269'3" Core 2: 270'9"	192'	283'	III
SB 8	Congaskraal	Core ?: top Core ?: 389' (top)	/	/ -	III
SB 9A	Platterug	Core 1: 282'6" Core 1: 285' Core 2: 290'	252'	294'	II
SB 10	Congaskraal	Core ?: 360'6" Core ?: ?363' (1' from bottom)	/	/	II
SB 13A	Tankatara	Core 1: 129' Core 2: 180'6"	/	182'	VII
SB 15	Nieuwjaarskop	Core 2: 210' Core 3: 222' Core 3: 225' Core 4: 229'	183'6"	236'6"	II
SB 18	Hopewell	Core 3: 302'6"	/	310'	?
SB 21	Cypherfontein	Core 3: 418'6"	/	419'	III
SB 24	Sea View	Core 1: 457'6"	372'6"	460'	III
SB 25	Sea View	Core 1: 796'9"	695'	770'	IV/V
SB 26	No data	Core 7: 378'6"	127'6"	383'	?
SB 27	Sundays River mouth	Core 1: 189' (?top) Core 1: 196'3" (?bottom)	120'	196'3"	IV
SB 28	Vetmaakvlakte	Core 1: 188' Core 1: 193'9"	147'	194'	VI
SB 29	Vetmaakvlakte	Core ?: 218'6"	/	/	VI
SB 31	Vetmaakvlakte	Core 1: 91'6"	20'	97'3"	IV
SB 32	Vetmaakvlakte	Core 1: 146' Core 1: 148' Core 2: 192'? (?2' below top) Core 2: 199'? (?bottom)	100'	199'	IV
SB 35	Doornkloof	Core ?: top	/	/	III



### *Outcrops*

Outcrops (Fig. 3, Table 3) have been sampled over a wide area of the Algoa Basin by Mr I. R. McLachlan and Mr C. Reabow, both of SOEKOR (Pty) Ltd. The majority of outcrops expose the Late Valanginian—lower part of the Sundays River Formation—and only the cliff exposures behind Colchester Station reveal the upper, Hauterivian portion. The Valanginian outcrops expose rocks that vary considerably in their depositional environment, from hyposaline and transitional (Dunbrody, The Look Out) to middle and outer shelf (Coega Brick Pits). The outcrops again provide control on the interpreted stratigraphic ranges of the foraminifera species recognized in the boreholes, since they also provide detailed *in situ* point data and a tie to the macrofossils. The variability of core results, discussed above, also holds true for the 122 outcrop samples, for the same reasons. The establishment of a detailed foraminifera biostratigraphy from the boreholes has helped achieve a close correlation between the borehole and outcrop sections. More specific detail on the outcrops is provided subsequently in this article (see p. 44).

### *Processing methods*

All samples were processed by standard micropalaeontological methods. All cuttings were sampled at a standard quantity (250 g) and processed using a Quaternary ammonium surfactant detergent (Tinegal PAC) of the type described by Zingula (1968). Irregular quantities of from 250 g to occasionally perhaps 500 g were sampled from the cores and outcrops. All samples were washed through 150-mesh (106 micron) sieves, and residues dried and separated into 30-mesh (500 micron), 60-mesh (250 micron), and 150-mesh fractions for ease of picking. Picking of specimens from processed cuttings samples was to a standard maximum of 400 foraminifera tests; from cores and outcrop residues the same procedure was followed, though more were picked in some cases where test preservation was particularly good (e.g. Coega Brick Pits).

## COMPARISON OF SUNDAYS RIVER FORMATION FORAMINIFERA WITH ELSEWHERE

Increasing research on time-equivalent rocks of the Sundays River Formation in southern South America has revealed the presence of very similar foraminifera faunas. The foraminifera of the Sundays River Formation do not compare particularly well with those of the Majunga Basin, Madagascar (Espitalié & Sigal 1963), although a few species occur in common. There is also only little similarity with the foraminifera of the Speeton Clay (Berriasian to Aptian) of north-east England and the time equivalent sequences of north-west Germany. No definite comparison is yet possible with anywhere else in the world. This is particularly unfortunate in the case of those continents previously constituents of East Gondwana: India, Australia and Antarctica.

### *Argentina and Chile*

Distinctive foraminifera assemblages have been described to date by many authors from the Early Cretaceous of southern Argentina and Chile. These include those described

by Bertels (1990), Kielbowicz *et al.* (1983), Malumián & Masiuk (1975), Malumián & Nañez (1983), Masiuk & Viña (1986a, 1986b, 1987), Musacchio (1978, 1979, 1980, 1981) and Simeoni (1985) on Argentinian faunas, and by Martínez & Ernst (1965) and Cañon & Ernst (1974) on Chilean faunas. Many derive from outcrops where associated ammonite data are available. However, it appears that the majority of the illustrated faunas are not very diverse, and generally not as diverse as faunas from time-equivalent rocks in southern Africa. The reason for this is unclear.

### *Berriasian–Valanginian*

Some of the oldest Cretaceous assemblages of foraminifera described to date are those from the Springhill Formation of the Bahia de la Lancha area east of Lago San Martín, Santa Cruz Province, Argentina (Kielbowicz *et al.* 1983) and in southern Chile (Martínez & Ernst 1965; Cañon & Ernst 1974: 46). Ammonites (*Jabronella*, *Neocosmoceras* and *Delphinella*) from the Santa Cruz exposures, described by Riccardi (1977, 1988), suggest a Berriasian, or Berriasian to earliest Valanginian age. The foraminifera described by Kielbowicz *et al.* (1983) were determined as Valanginian. Although they compare closely to assemblages of the lower part of the Sundays River Formation (Late Valanginian in age), they are also similar to those seen in South African Early Valanginian or latest Berriasian marine rocks distal of the Kirkwood Formation red beds. The presence of *Lenticulina nodosa* (Reuss) and *Dorothia australis* sp. nov. (as *Marssonella kummi* Zedler) indicate an age for the Springhill Formation of no older than latest Berriasian, in South African terms. This is reinforced by the occurrence of *Planularia tricarinelina* (Reuss) (as *Cristellaria tricarinelina*) in the Chilean Springhill Formation (Martínez & Ernst 1965), a species present in the latest Berriasian to Early Valanginian (though also early Barremian) of South Africa. Also notable in the Springhill assemblages detailed by Kielbowicz *et al.* (1983) is the finely, uniformly reticulated, surface-ornamented *Astacolus microdictyotos* Espitalié & Sigal tests, also seen in examples from the Portlandian to Early Hauterivian of South Africa. Lacking in the Springhill Formation is *A. gibber* Espitalié & Sigal, again suggesting a pre-Late Valanginian age. It should be noted, however, that offshore seismic work by Carbone (1990) indicates the Springhill sandstones and Pampa Rincón claystones to be interbedded, so that the Springhill Formation is evidently a diachronous sandstone facies (see also Biddle *et al.* 1986).

### *Valanginian–Hauterivian*

From the Pampa Rincón Formation of Tierra del Fuego and Estratos con *Favrella* of southern Argentina and Chile, regarded by Malumián & Masiuk (1975) as Valanginian–Hauterivian, *Pseudopolymorphina martinezi* (Cañon & Ernst), *Lenticulina nodosa* and *Astacolus gibber* are found to be common. Unfortunately, no mention is made by Malumián & Masiuk (1975) of associated macrofaunal elements such as ammonites, since their study was based on borehole cuttings. Natland *et al.* (1974) reported on *Favrella* ammonites in outcrops of Rinconian age (probably Hauterivian rather than Oxfordian to Kimmeridgian as originally defined). Riccardi (1988) has regarded the *Favrella* faunas as of Early Hauterivian to earliest Barremian age.



Foraminifera assemblages of about the same age have been described from the Katterfeld Formation of Chubut, Argentina (Masiuk & Viña 1986b, 1987), dated as Early Hauterivian, and from the Agrio Formation of Neuquén, Argentina (Musacchio 1978, 1979, 1981; Simeoni 1985; Masiuk & Viña 1986a, 1986b), dated as Late Valanginian or Early Hauterivian to Late Hauterivian or Early Barremian. Similarities occur with the Sundays River Formation but generally only with individual described species rather than whole assemblages. Little comment is made on microfaunal–macrofaunal associations by the authors, although Masiuk & Viña (1986a) reported *Crioceratites andinus* (Gerth) in association with one foraminifera assemblage studied from the upper part of the Agrio Formation, and *Olcostephanus* cf. *atherstoni* (Sharpe) and *Olcostephanus curacoensis* Weaver with a different, lower, assemblage. The former assemblage is regarded as Late Hauterivian, the latter as Late Valanginian in age. The latter seems to be the only Argentinian one published to date that is clearly associated with *Olcostephanus ammonites*.

Musacchio (1979) determined the presence of two foraminifera assemblages in the Hauterivian of the Agrio Formation. The Early Hauterivian assemblage appears to be very much the poorer, and none of the foraminifera species appears to be age diagnostic: ammonites in association with this assemblage include *Holcoptychites neuquensis* (Douvillé) and *Pseudofavrella* spp. The second, Late Hauterivian assemblage contains diverse foraminifera. However, the presence of hedbergellids (Musacchio 1979, pl. 5 (figs 20, 25)) strongly suggests that later Early Barremian foraminifera are also represented in this second assemblage, as the illustrated examples are very similar to *Praehedbergella sigali* (Moullade), as understood in South Africa. The Late Hauterivian assemblage is associated with diverse species of *Crioceratites* ammonites. It seems possible that the foraminifera described by Masiuk & Viña (1986b) from their upper Agrio Formation sample, and those described by Musacchio (1979) from Site 5 (Río Agrio), are from the same, or almost the same locality. Just to the east of this site, at Agrio del Medio are Early Barremian rocks with *Plesiospitidiscus* and *Spitidiscus* (Leanza & Wiedmann 1992).

#### *Hauterivian–Barremian*

Malumián & Nañez (1983) illustrated a foraminifera assemblage from the upper Río Mayer Formation of Santa Cruz province, southern Argentina, which is dominated by *Epistomina caracolla* (Roemer) s.l. This assemblage is very similar to South African ones from an organic-rich, high-gamma claystone interval developed locally on the continental shelf in the Bredasdorp and Pletmos Basins and at the base of the Cretaceous drift succession in Zululand, and regarded on foraminifera grounds as later Early Barremian in age. Malumián & Nañez (1983) reported the presence of *Hatchericeras patagonense* Stanton and other ammonite species with the studied sample, again suggesting an Early Barremian age (Riccardi 1988). Bertels (1990) also studied the Río Mayer Formation, apparently the same Bahía de la Lancha, Lago San Martín section from which Kielbowicz *et al.* (1983) studied the Springhill Formation foraminifera. The assemblage described by Bertels (1990) from the basal Río Mayer Formation clearly shows close similarities with



the foraminifera from the upper Sundays River Formation, as *Lingulina trilobita* sp. nov., *Paralingulina hexacarinata* (Espitalié & Sigal) and the *Psilocitharella kochii* (Roemer)–*P. arguta* (Reuss) group mutually occur. Overlying beds in the Río Mayer Formation contain a poor fauna with *Lenticulina nodosa* (Reuss), that may prove to be Barremian and Early Aptian in age. However, the more diverse assemblages recognized by Bertels (1990) in the upper third of the Río Mayer Formation, characterized by *Tritaxia* sp. aff. *T. pyramidata* Reuss and *Glomospira charoides* Jones & Parker, are clearly unlike any Barremian–Early Aptian assemblages known in South Africa, and must be of Late Aptian (to ?Early Albian) age. These species do occur widely in the South African Late Aptian and Albian, primarily in slope environments. From essentially the same outcrop, *Favrella* species of ammonites occur in the basal Río Mayer Formation, suggesting a Hauterivian age, whereas in the upper part of the formation Aptian and Albian species occur (Aguirre Urreta 1986; Riccardi 1988).

#### DSDP Site 249, Mozambique Ridge

Riegraf (1989) described Valanginian–Hauterivian foraminifera assemblages from cores 26–31, DSDP hole 249, leg 25, in the south-western Indian Ocean. This section unconformably overlies vesicular amygdaloidal glassy basalt. The assemblages are diverse, and contain a number of species in common with those of the Sundays River Formation, but also a number of forms that suggest these basal sediments intersected in hole 249 are later in age than the uppermost Sundays River Formation, later than Hauterivian. Although *Lingulina mngazanaensis* sp. nov. (as *Lingulina* sp. B), *Lenticulina nodosa* (Reuss), *Astacolus microdictyotos* Espitalié & Sigal, and *Citharina harpa* (Roemer)–*C. pseudostriatula* Bartenstein & Brand occur in common, the presence of *Planularia tricarinnella* (Reuss) (as *Palmula crepidularis* (Roemer)), *Gavelinella barremiana* Bettenstaedt, and, possibly *Pseudopolymorphina* ‘*carinata*’ (as *Globulina bucculenta* (Berthelin), but only plate 2 (fig. 18) of Riegraf 1989) suggest a later age. *Planularia tricarinnella* and *Pseudopolymorphina* ‘*carinata*’ occur in association in the later Early Barremian of the southern offshore (McMillan *et al.* 1997) and in the basal drift Cretaceous of the Zululand onshore boreholes, and for this reason the DSDP 249 assemblages detailed by Riegraf (1989) are considered to be essentially of Barremian age rather than Valanginian–Hauterivian. It is as yet not clear if *Pseudopolymorphina* ‘*carinata*’ is synonymous with *P. martinezi* Cañon & Ernst, known from southern Chile and Argentina (Cañon & Ernst 1974: 75, pl. 2 (fig. 8a–c); Malumián & Masiuk 1975: 594, pl. 1 (fig. 2a–c), pl. 2 (fig. 1)), since the degree of inflation of the later chambers is seemingly much greater in the South American than in the South African specimens. Other features of these tests, however, such as the apical spine, the acute, often carinate periphery and the manner in which the test tapers up to the aperture, are all remarkably similar.

#### AGE OF THE SUNDAYS RIVER FORMATION

Comparisons between the foraminifera species of the Sundays River Formation and those of several regions elsewhere in the world have been made above, but precise datings

of the Formation using foraminifera have proved to be rather difficult to achieve. A summary of the following data is shown in Figure 6. In the northern Algoa Basin, the most complete borehole section of the Sundays River Formation is that of AL 1/69. The latest assemblages (Biozone I) of AL 1/69 do not contain any of those benthonic foraminifera that herald the appearance of the calcite-walled *Rotaliina*. In Europe, *Gavelinella sigmoicosta* (Ten Dam) is the precursor of the *Gavelinella* lineage, and this appears in the latest Hauterivian or earliest Barremian (Bartenstein & Bettenstaedt 1962; Fletcher 1973; Bartenstein & Kaever 1973; Malapris-Bizouard 1974). Subsequently, in the Early Barremian, the *Conorotalites* lineage commences (Bartenstein & Bettenstaedt 1962). Foraminifera faunas in the highest Sundays River Formation are diverse, and there is no reason to suppose that early species of either *Gavelinella* or *Conorotalites* were prevented in some way from inhabiting the Algoa Basin embayment. At about the Hauterivian–Barremian boundary, hedbergellid planktonic foraminifera begin to appear in the Mediterranean region (Moullade 1974), and there is a marked diversification of the group at this time (Banner & Desai 1988, fig. 1), and an extension of geographic range, from low western latitude-restricted to low and high latitudes. Thus, rock sequences dated as later Early Barremian (post 6At1) in the southern offshore Pletmos and Bredasdorp basins contain the earliest planktonics seen in South Africa: *Gorbachikella kugleri* (Bolli) and, less commonly, *Praehedbergella sigali* (Moullade), and some *Gavelinella* spp. also occur. This later Early Barremian planktonic event has also been recognized in the North Sea (King *et al.* 1989, fig. 8.5). In contrast, planktonic foraminifera are absent throughout the Sundays River Formation and its time equivalents around southern Africa, in all marine depositional environments studied.

Comparison with benthonic foraminifera faunas from the oldest marine beds of the Zululand onshore boreholes reveals some species in common with the Sundays River Formation, but these are mostly species that range through much or all of the Sundays River succession. These oldest Zululand marine sediments are regarded as of much the same age as the (?Late) Barremian outcrops, detailed by Kennedy & Klinger (1975) as containing crioceratitid and other ammonites. More recently, Kennedy & Klinger (1990) have reported *Hatchericeras patagonense* Stanton from these outcrops, suggesting an earlier Barremian age. As noted above, occasional floods of *Epistomina caracolla* (Roemer) s.l. occur in the Zululand later Early Barremian, that have analogues in the Pletmos and Bredasdorp Basins, and in the Río Mayer Formation of Argentina (Malumián & Nañez 1983): these *Epistomina* are morphologically distinct from those of the Late Valanginian and Hauterivian. *Lenticulina nodosa* (Reuss), *Astacolus gibber* Espitalié & Sigal, *A. microdictyotos* Espitalié & Sigal, and forms similar to *Reinholdella valendisensis* (Bartenstein & Brand) also occur in the Zululand later Early Barremian. However, other aspects of these benthonic foraminifera assemblages tend to be unlike those of the Sundays River Formation, particularly the agglutinated, *Pseudopolymorphina*, *Pseudonodosaria* and other nodosarid species. Despite the rather ambiguous state of available data, it is felt that the highest Sundays River Formation beds are slightly older than the oldest of the later Early Barremian rocks of Zululand, and are latest Hauterivian in age.



The lower third of the Sundays River Formation is characterized by the presence of the two benthonic aragonitic foraminifera *Reinholdella valendisensis* (Bartenstein & Brand) and *R. hofkeri* (Bartenstein & Brand), which in north-west Europe range from the basal Berriasian to the Valanginian–Hauterivian boundary (Fletcher 1973; Bartenstein 1976a, 1976b). These two species first appear down-hole near the first down-hole occurrence of *Cytherella algoaensis* Brenner & Oertli, and have been taken to mark the foraminiferal top of the Valanginian in the Sundays River Formation. However, more recent Northern Hemisphere records of the species suggest that *R. valendisensis* may range locally as high as Late Hauterivian (Jansa *et al.* 1980) and *R. hofkeri* as high as Late Barremian (Ascoli 1976) off the Atlantic coast of Canada. For the present study, these two species are retained as local index fossils for the Valanginian. It is intriguing how very rarely these species of *Reinholdella* have been reported in the literature from the Early Cretaceous succession of Argentina (only Masiuk & Viña 1986a have identified *R. hofkeri*), when compared with their widespread distribution around South Africa.

The presence of *Trocholina infragranulata* Noth in the outcrops at Brenton and Mngazana, in association with assemblages that compare very closely to those of the lowest Sundays River Formation, suggest that the Formation at oldest is of mid-Valanginian age (see Bartenstein 1976b). Southern offshore boreholes drilled by SOEKOR indicate that *Astacolus gibber* Espitalié & Sigal ranges no further down section than mid-Valanginian (base Sundays River Formation equivalent). This species occurs through almost all of the Sundays River Formation. In the offshore Pletmos, Gamtoos and Algoa basins, the Valanginian can be divided into two: a late Valanginian portion, in which foraminifera faunas are very similar to those of the lower Sundays River Formation, and an early Valanginian portion, in which the foraminifera are mostly dissimilar. For all these reasons, the oldest Sundays River Formation is thus regarded as being of mid-Valanginian age.

## LITHOSTRATIGRAPHY

As mentioned previously, the stratotype of the Sundays River Formation was designated the Zoetgeneugd Cliff outcrop by Winter (1973); a subsurface stratotype was also designated: borehole CO 1/67 from 30 m to 1 028 m (preferentially 100 ft and 3 373 ft, since the borehole was drilled, and the core marked up in feet). However, apart from the preliminary lithological work of Venter (1972f), and the comments on the ostracod faunas by Brenner & Oertli (1976) and Valicenti & Stephens (1984), no precise attempt has been made to relate the surface and subsurface stratotypes. Much of the lithology of the Sundays River Formation is composed of repetitive claystones and sandstones, both variably silty, and variable in thickness. A typical interval of the upper Sundays River Formation in CO 1/67 (Biozones VII to VIII) is illustrated by Winter (1973, fig. 2). Because of the repetitive nature of the Sundays River sequence, lithological marker beds are rare, and subdivisions can be made most easily only on palaeontological and log/seismic characteristics.

Venter (1972a, 1972c, 1972d, 1972f, 1972g) subdivided the Sundays River Formation



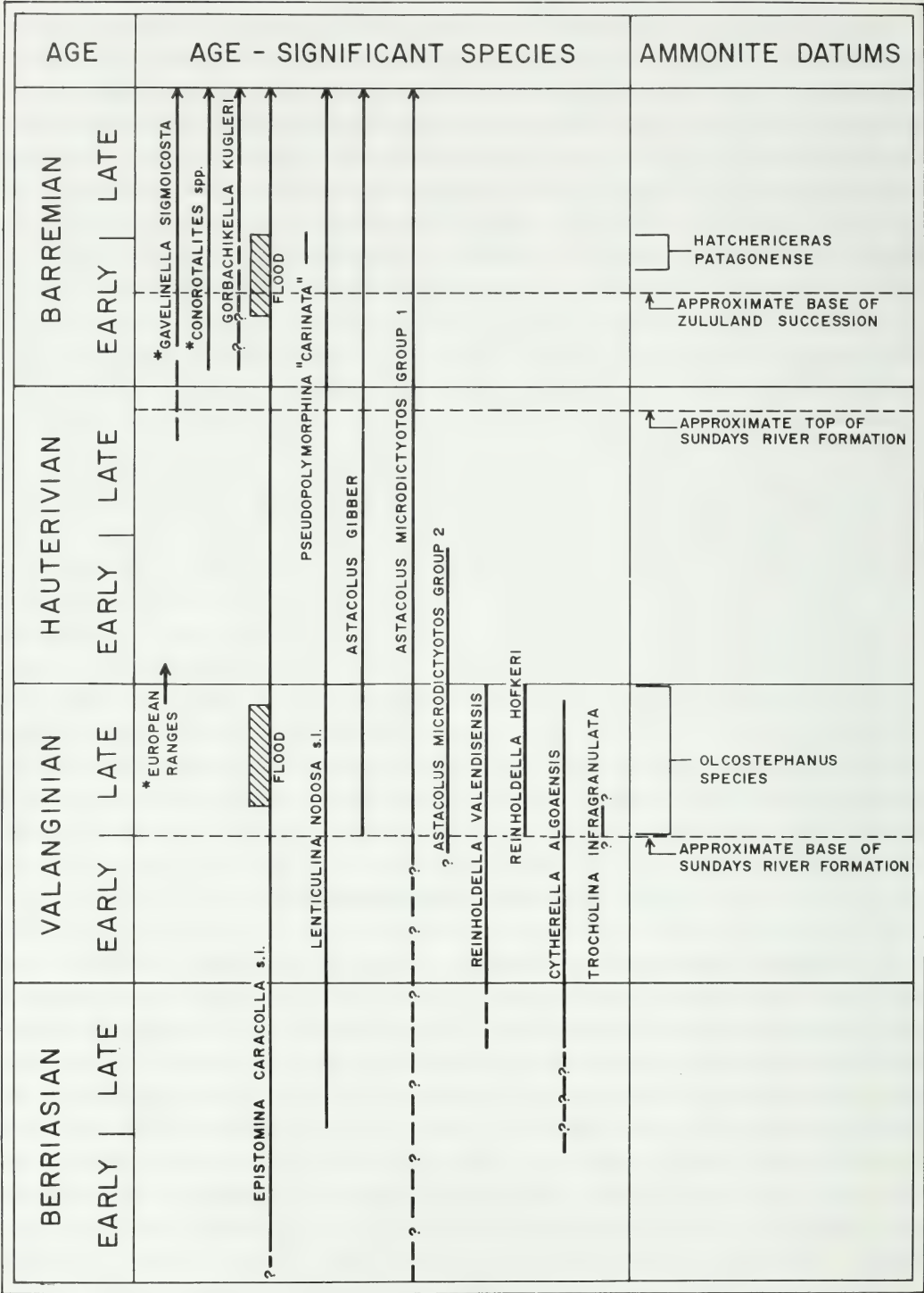


Figure 6.  
Interpreted stratigraphic ranges of age-diagnostic foraminifera species  
utilized in establishing the age-span of the Sundays River Formation.

into four members, based on the CO 1/67 fully-cored stratotype section: from bottom to top these are the Amsterdamhoek, Soetgenoeg, Addo and Vetmaak Members. Their relationships have been shown by Winter (1979, fig. 6). A number of smaller-scale rock units were also recognized by Venter (1972*c*) that show distinctive characteristics in the CO 1/67 stratotype. The four members were determined in other deep borehole sections by Leith (unpublished data) during the early 1970s, when exploration drilling was at its height. Since then, with declining economic interest in the onshore Algoa Basin, no further lithostratigraphic work has been undertaken on the type Sundays River Formation within SOEKOR. Indeed, with the increasing realization of the complex variations evident in depositional environment, and consequent variations in lithotype, in synrift and transitional rift rocks of the same age from the different offshore basins (Bredasdorp, Pletmos, Gamtoos and Algoa), the whole question of formalized lithostratigraphy has been avoided in SOEKOR hydrocarbon exploration activity.

The four Members recognized by Venter (1972*c*) and Winter (1979) have been accorded formal status (SACS 1980: 579). As pointed out by Winter (1979: 188), however, almost all other boreholes drilled to date in the onshore part of the Algoa Basin are rotary, cuttings holes, so that correlation must be achieved either via electric log markers, or via biostratigraphy. Electric log correlations were attempted by Venter and Leith in the early 1970s, but again the repetitive, cyclical nature of the Sundays River Formation has led to the identification of few clear-cut, distinctive log horizons. According to Winter (1973: 31) and MacKeith *et al.* (1976), seismic reflectors too are often intermittent and correlations between boreholes are thus hindered. 'Shaling-out' of sandstone intervals basinwards also limits any proposed lithostratigraphic scheme. The electric log correlations shown in Figure 7 are based on a table compiled by Leith in October 1975, plotted against the microfaunal biozonation described herein. Only those boreholes in which electric log correlations have been attempted are included. It is clear that although similar trends are evident in both the log and foraminifera correlations, sufficient difference exists between the two that the boundaries of the four established lithostratigraphic members cannot be clearly defined across the entire Sundays River Trough. Similar doubts exist over precise positionings of boundaries of the four lithostratigraphic members in the various outcrops of the Sundays River Formation. Furthermore, the use of the four names Amsterdamhoek, Soetgenoeg, Addo and Vetmaak, based primarily on farm names of outcrops, indicates a stratigraphic relationship of these outcrops that is not confirmed from this foraminifera study.

Because of the incomplete status of lithostratigraphic subdivisions of the Sundays River Formation, they have not been considered further in the present study. Much additional work is necessary to establish the Members defined by Venter (1972*c*), and formalized by Winter (1979) and SACS (1980), across the Sundays River Trough, to determine the Member(s) of the topmost part of the Sundays River Formation in the basin axis (especially in boreholes KE 1/71 and AL 1/69), and to determine the lithostratigraphic status, if any, of the five 'Zones' of the Amsterdamhoek Member, the five 'Zones' of the Soetgenoeg Member, and the two divisions of the Vetmaak Member defined by Venter (1972*c*) in the CO 1/67 cored hole.





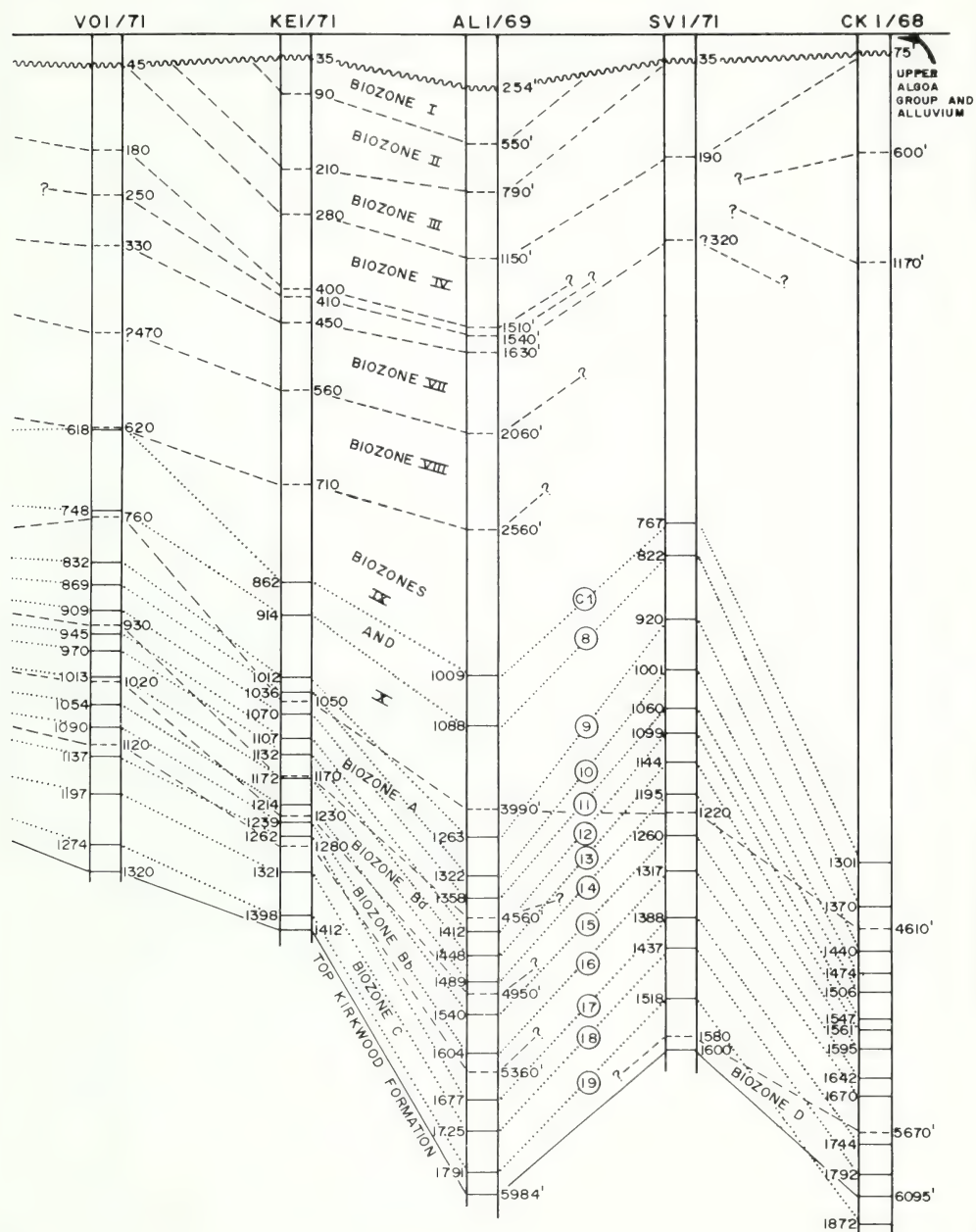


Figure 7 (CONTINUED).

STAGE	BRENTON	PB - A1	ALGOA BIOZONATION	MNGAZANA	ALGOA OUTCROPS
BARREMIAN EARLY		(6At1)	(6At1)		
H A U T E R I V I A N E A R L Y			BIOZONE I <i>Reinholdella platterugensis</i>		
		<700'	BIOZONE II <i>Later Epistomina hechti</i>		
		750'	BIOZONE III <i>Amphicaryna pietmosiana</i>		
		960'	BIOZONE IV <i>Pseudopolymorphina colchesterensis</i>		
			BIOZONE V <i>Early Epistomina hechti</i>		
			BIOZONE VI <i>Dorothia inglisidensis</i>		
			BIOZONE VII <i>Vaginulinopsis cf. matulina</i>		
			BIOZONE VIII <i>Later poor zone</i>		
		1140'	Top <i>Reinholdella v. plattenbergia</i>		
			BIOZONE IX <i>Eoguttulina</i> sp. B.		
V A L A N G I N I A N L A T E					
W A R M I N G T O N I A N L A T E					
W A R M I N G T O N I A N E A R L Y					

Figure 8.

Interval biozonation of the Sundays River Formation based on foraminifera, compared with biozonations of the time-equivalent section in the north Pletmos Basin (PB-A1 borehole and Brenton outcrop) and the Mngazana Basin. Interpreted stratigraphic ranges of studied Algoa outcrop sections are also shown.

## FORAMINIFERAL BIOZONATION OF THE SUNDAYS RIVER FORMATION

Ten Hauterivian and five Late Valanginian foraminifera biozones have been recognized in the Sundays River Formation. The biozones are formally described here; they have been numbered from the top of the section downwards, since most of the data upon which they are based have been derived from borehole sections affected by cavings. Biozone tops are marked by first down-hole appearance of selected species or other characteristics, so that this biozonation is essentially an interval zonation as defined by Hedberg (1976). For distinction, the Hauterivian biozones are denoted with Roman numerals, and the Late Valanginian ones with Roman letters. The interpreted chronostratigraphy of the foraminifera biozonation and relationships with other published time-equivalent sections are shown in Figure 8. The interval biozonation for all studied deep boreholes, with the lithology, is shown in Figure 9\*. Foraminifera abundance is displayed against the interval biozonation of the deep boreholes in Figure 10\*.

### LATE HAUTERIVIAN

#### **Biozone I.**

##### *Reinholdella platterugensis* Zone (Partial Range Zone)

**Definition.** Interval from the first down-hole appearance of *Reinholdella platterugensis* to the first down-hole appearance of *Epistomina hechti*.

**Notes.** This biozone is preserved only in the basin axis around boreholes KE 1/71 and AL 1/69. Maximum thickness is 90 m in AL 1/69. The upper surface of Biozone I is everywhere unconformable, and overlain by the Pleistocene upper Algoa Group. Outcrops may occur in the Spring Valley area, but these are probably very limited. Diverse foraminifera faunas occur through most of the interval, but some weathering and leaching appears to have occurred immediately below the Hauterivian–Pleistocene unconformity. Foraminifera faunas generally remain diverse throughout Biozones I to VII, reflecting a predominance of clay lithologies. This uniformity of the top seven biozones distinguishes them, and permits them to be separated as Late Hauterivian in age.

#### **Biozone II.**

##### Upper *Epistomina hechti* Zone ('Total' Range Zone)

**Definition.** Interval between first down-hole appearance of *Epistomina hechti* and the first down-hole appearance of *Amphicoryna pletmosiana*.

**Notes.** Biozone II is also confined to the boreholes of the basin axis: KE 1/71 and AL 1/69. Maximum thickness of 120 m occurs in KE 1/71; the AL 1/69 section, probably more precisely, is 73.2 m thick. Again, outcrops of Biozone II are confined to the Zoekamma–Spring Valley area, and the biozone is mostly concealed beneath the

\* Figures 9 and 10 are fold-out charts placed at the back of this Volume.



Pleistocene deposits of the upper Algoa Group. Foraminifera faunas are diverse and abundant for the most part, though there are some sandy intervals in which only *Ammobaculites subaequalis* Mjatliuk and *Bullopore laevis* (Sollas) predominate.

### **Biozone III.**

*Amphicoryna pletmosiana* Zone (Partial Range Zone)

*Definition.* Interval between the first down-hole appearances of *Amphicoryna pletmosiana* and of *Pseudopolymorphina colchesterensis*.

*Notes.* Biozone III is also confined to the basin axis, in boreholes AL 1/69, KE 1/71, SV 1/71 and CO 2/70. There is a strong possibility that this biozone is also represented at the top of the Sundays River Formation in VO 1/71, but the microfauna recovery was not good enough to confirm this. The faunas of Biozone III are much the same as for the overlying zone. Average thickness of biozone is 100 m.

### **Biozone IV.**

*Pseudopolymorphina colchesterensis* Zone (Total Range Zone)

*Definition.* Interval between the first down-hole appearance of *Pseudopolymorphina colchesterensis* and its last appearance, which exactly equates to the second down-hole appearance of *Epistomina hechti*.

*Notes.* Biozone IV has been recognized at or near the top of the Sundays River Formation in boreholes CO 2/70, CO 3/71, VO 1/71, SM 1/76, NA 3/70, and probably also in CK 1/68. It may also occur in NA 1/69 and NA 2/70 at top-hole, but the facies there is too marginally marine for the biozone species and its associated foraminifera to occur. The biozone outcrops in the upper two-thirds of the kloof section studied at Colchester Cliff. Foraminifera faunas remain much as above. Average thickness of Biozone IV is 100 m.

### **Biozone V.**

Lower *Epistomina hechti* Zone ('Total' Range Zone)

*Definition.* Interval between second major down-hole appearance of *Epistomina hechti* and first down-hole appearance of *Dorothia inglesidensis*.

*Notes.* The lower *Epistomina hechti* zone occurs in all of the boreholes listed under Biozone IV, together with CO 1/67. Due to differences in facies, it cannot be identified on the basis of the foraminifera in SV 1/71, NA 3/70, NA 2/70, NA 1/69 and CK 1/68, but thicknesses and adjacent biozones indicate it to be present. Biozone V probably outcrops in the cliffs facing the Sundays River about the farm Ingleside 215 and in the lower Colchester Cliff: elsewhere it is obscured by the upper Algoa Group. Foraminifera faunas remain much the same as above. Thickness varies from 90 m (CO 3/71) to 10 m (KE 1/71): minimum thicknesses prevail in the basin axis.

### **Biozone VI.**

*Dorothia inglesidensis* Zone (Partial Range Zone)

*Definition.* Interval between first down-hole appearance of *Dorothia inglesidensis* and first down-hole abundance of *Vaginulinopsis* cf. *V. matutina*.

*Notes.* The distribution of Biozone VI is exactly the same as that of overlying Biozone V, except that it can also be recognized in borehole SV 1/71. Biozone VI may outcrop in the cliffs along the eastern margin of the Sundays River valley. During this interval, foraminifera faunas begin to decline in diversity and abundance.

### **Biozone VII.**

*Vaginulinopsis* cf. *V. matutina* Zone (Partial Range Zone)

*Definition.* Interval between first down-hole abundance of *Vaginulinopsis* cf. *V. matutina* and the abrupt decrease in foraminifera diversity and abundance at the top of the Upper Poor Zone.

*Notes.* This biozone must outcrop or subcrop beneath the upper Algoa Group in the area west of the Sundays River valley, on the farms Tankatara and Melville, and also subcrop north of the NA boreholes, amongst other places. However, because of the marginal marine facies in the north and east, the precise interval of the biozone cannot be determined in these areas. The decline in foraminifera diversity and abundance continues through Biozone VII.

## EARLY HAUTERIVIAN

### **Biozone VIII.**

Upper Poor Zone (Assemblage Zone)

*Definition.* Interval between abrupt decrease in foraminifera diversity and abundance, and first down-hole appearance of *Eoguttulina* sp. B.

*Notes.* Biozone VIII has much the same geographical distribution as Biozone VII. In the cleaner cuttings boreholes least affected by down-hole cavings, the top of Biozone VIII is clearly evident, but in the less cleanly drilled holes, cavings obscure the abrupt decrease in foraminifera. Only after caved material has been identified and excluded, using the cleaner holes as comparisons, can the top of the biozone be identified in the poorer holes. A different problem exists in the case of the fully-cored borehole CO 1/67, where diversities of foraminifera fluctuate widely even in adjacent samples, partly in response to the cyclical lithology. Since, through selection, the cored samples studied have tended to be clayey, occasional core samples from Biozone VIII in CO 1/67 contain abundant faunas that are not represented in nearby cuttings holes where the sampling interval is 3 m, 5 m or 10 m. As a result, the top of Biozone VIII in CO 1/67 has been estimated.

Foraminifera faunas of Biozones VIII, IX and X tend to be dominated by agglutinated foraminifera, particularly of the genera *Haplophragmoides* and *Ammobaculites*. The diverse nodosarid and *Epistomina-Reinholdella* aspects of the overlying beds are generally lacking. For these reasons the three biozones have been regarded as of Early Hauterivian age, although there is no available faunal evidence to confirm precisely such an age.

### **Biozone IX.**

*Eoguttulina* sp. B Zone (Partial Range Zone)

*Definition.* Interval between first down-hole appearance of *Eoguttulina* sp. B and the

first down-hole appearance of *Dorothia australis*.

*Notes.* Biozone IX is again characterized by poor foraminifera assemblages. *Eoguttulina* sp. B is one of only a few species that first appear down-hole in the Early Hauterivian. Thicknesses of this biozone show some variation, from about 247 m in SM 1/76 down to less than 100 m in CO 1/67. This time period appears to have been one of substantial re-organization of the sedimentation process in the Algoa Basin, following the major, but abrupt, tectonic disturbance that occurred in latest Valanginian times (responsible for the 1At1 unconformity). Because of this, and the high frequency of sandstones over this interval in consequence, *Eoguttulina* sp. B cannot be recognized everywhere, and the foraminifera faunas remain poor.

### **Biozone X.**

*Dorothia australis* Zone (Partial Range Zone)

*Definition.* Interval between first down-hole appearance of *Dorothia australis* and first down-hole appearance of *Reinholdella valendisensis*.

*Notes.* Biozone X, on the basis of the distribution of *Dorothia australis*, can only be recognized intermittently in the onshore Algoa Basin, because of the fairly sandy nature of this part of the section. Offshore, the biozone is widely developed in the Bredasdorp, Pletmos, Gamtoos and Algoa basins. It is the highest biozone recognized in the Uitenhage Trough, adjacent to the bounding Coega Fault. In the Sundays River Trough, Biozone X probably outcrops in the vicinity of borehole BR 1/71, and probably also in the Canteen Kop area in the eastern Sundays River valley.

## LATE VALANGINIAN

### **Biozone A.**

*Reinholdella valendisensis* Zone (Partial Range Zone)

*Definition.* Interval between first down-hole appearance of *Reinholdella valendisensis* and the first down-hole appearance of *Lenticulina coegaensis* sp. nov.

*Notes.* As mentioned earlier, *Reinholdella valendisensis* and *R. hofkeri* have been used to mark the top of the Valanginian, both in the Algoa Basin and elsewhere in the southern offshore of South Africa. The first down-hole appearance of the ostracod *Cytherella algoaensis* Brenner & Oertli usually occurs within Biozone A.

Biozone A is not always easy to recognize in the northern Algoa Basin. In those boreholes that intersected a more sandy sequence, the two species of *Reinholdella* are rare, occasionally even absent, as far down as the top of Biozone B. In such cases, the top of Biozone A can only be recognized by the occurrence of tests of *Epistomina caracolla* that are preserved with a dark, rich golden-brown colour, profoundly different from the pale colour of Hauterivian tests of this species. However, when the sequence is clayier, common *Reinholdella valendisensis* and *R. hofkeri*, with abundant *Epistomina caracolla*, appear very abruptly, and provide a clear upper boundary for this zone. Because of the major change in test preservation from the top of Biozone A and downwards, and the abrupt appearance of the biozone markers, it seems likely that some form of unconformity



or hiatus occurs at this level, although the duration of any time gap cannot be determined from the foraminifera data. Examination of offshore borehole sections in the Pletmos and Gamtoos basins (boreholes drilled to date in the offshore Algoa Basin do not intersect a sufficiently shallow marine, shelf sequence to allow a comparison) has revealed no obvious seismic break at the level of the first down-hole appearance of *R. valendisensis*.

### **Biozone Ba.**

*Lenticulina coegaensis* sp. nov. Zone (Partial Range Zone)

**Definition.** Interval between first down-hole appearance of *Lenticulina coegaensis* sp. nov. and the first down-hole appearance of abundant *Sculptobaculites goodlandensis*.

**Notes.** Foraminifera faunas are generally very much more diverse and abundant in Biozones Ba and Bb, excluding those areas in the north and east in which estuarine and transitional environments prevailed. The dominant foraminifera are the *Epistomina caracolla* group, which, with *Reinholdella hofkeri* and *R. valendisensis*, ensures that most assemblages from Biozones Ba and Bb are composed mainly of aragonitic-walled species. This preponderance is in direct contrast to the foraminifera-rich interval in the Late Hauterivian, where nodosarids predominate. The dominance of aragonitic shells in much of the Late Valanginian appears to correspond to the predominance of *Cytherella* in Late Valanginian ostracod assemblages, and its lesser frequency in the Hauterivian (Brenner & Oertli 1976; Valicenti & Stephens 1984).

At or near the top of Biozone Ba lies the time-equivalent level of the major offshore unconformity seismically designated 1At1. This, at least in part, is evident in borehole lithologies as a change from sands and rare clays above to clays and rare sands below. Attempts to identify the unconformity with compaction breaks on the borehole electric logs have not proved particularly successful, possibly because the quality of the logs is often rather poor.

Biozones Ba and Bb combined (Biozone B) can be recognized extensively in the offshore portions of the Pletmos, Gamtoos and Algoa basins, where both the first down-hole, and last down-hole appearances of *Lenticulina coegaensis* sp. nov. have proved to be of stratigraphic significance.

### **Biozone Bb.**

*Sculptobaculites goodlandensis* Zone (Partial Range Zone)

**Definition.** Interval between first down-hole appearance of abundant *Sculptobaculites goodlandensis*, and the abrupt decrease in foraminifera diversity and abundance at the top of the Lower Poor Zone.

**Notes.** Foraminifera assemblages of Biozone Bb are essentially the same as those of Biozone Ba. *Sculptobaculites goodlandensis* appears to be confined to the onshore Algoa Basin, so that the distinctions of the two biozones cannot be made offshore. The Coega Brick Pits, northernmost cutting of the Uitenhage to Graaff-Reinet Road, the upper three-quarters of the Zoetgeneugd Cliff outcrop, and the Amsterdamhoek exposure are all of Biozone Bb age.

### **Biozone C.**

#### **Lower Poor Zone (Assemblage Zone)**

*Definition.* Interval between abrupt decrease in foraminifera abundance and diversity (near to last down-hole appearance of *Lenticulina coegaensis* sp. nov.) and the first down-hole appearance of *Miliammina latrobei* sp. nov., or top red beds.

*Notes.* Poor foraminifera assemblages, dominated by *Ammobaculites* and *Haplophragmoides* species, with calcareous forms such as *Lenticulina nodosa* and *Astacolus calliopsis* are typical in the interval of Biozone C. Subsequent to the major decrease in abundance and diversity that marks the top of the biozone, there is a fairly steady decline in both parameters through the biozone, with the lower part being virtually devoid of all types of foraminifera. Because of caving problems in a number of the rotary holes, the sequence of events is somewhat obscured over this interval, but the degree of caving can often be determined from the presence or absence of obviously caved tests occurring in the underlying red beds samples of the non-marine Kirkwood Formation. The fully-cored CO 1/67, AD 1/68 and PA 1/68 sections are also of help in determining the true foraminifera abundance through this interval. The lowest part of the Zoetgeneugd Cliff, the middle cutting on the Uitenhage to Graaff-Reinet Road, and the Airedale outcrops are referable to Biozone C.

### **Biozone D.**

#### ***Miliammina latrobei* sp. nov. Zone (Total Range Zone)**

*Definition.* Interval between first down-hole appearance of *Miliammina latrobei* sp. nov. and the first consistent down-hole appearance of red and green beds (top Kirkwood Formation).

*Notes.* This biozone can not be extensively recognized, partly because of the difficulty of obtaining *Miliammina latrobei* sp. nov. specimens from cuttings samples. The full areal distribution of the biozone is thus in some doubt. The biozone is evident in cored borehole CO 1/67, and in the northern and eastern boreholes where marginal marine and estuarine facies predominate (NA holes, PA 1/68 and CK 1/68). *Miliammina latrobei* sp. nov. seems to be confined to estuarine and possibly other reduced salinity environments, as are most *Miliammina* species at the present day. Thus it appears that Biozone D, of all those recognized in the northern Algoa Basin, is the one most likely to suffer facies-induced diachroneity. The outcrops of The Look Out and Dunbrody areas are referred to Biozone D—since *M. latrobei* sp. nov. occurs in the stratigraphically highest of these, at The Look Out, and at the low-level bridge just to the west. Foraminifera here are sparsely present, or more often absent.

In the CO 1/67 section (Figs 4, 81), which is probably fairly representative of all the basin centre wells, core sampling was undertaken at close intervals, with some parts of the section being sampled at as close as 2-foot intervals. It is clear that microfaunas in the lower part of Biozone C are very poor, but these rocks are distinctly marine, since they contain numbers of gastropods, bivalves and echinoderm skeletal fragments. Foraminifera appear more consistently from the top of Biozone D downwards, but they are almost exclusively *Miliammina latrobei* sp. nov. Near the base of Biozone D, at 3 356 ft

(1 022.9 m), a sudden, marked increase in foraminifera occurs, with large numbers of *Ammobaculites* and *Haplophragmoides* tests (one or two species of each). No attempt has been made to develop this *Ammobaculites*–*Haplophragmoides* interval as a formal biozone, as it has only been recognized in the CO 1/67 section, and, given the circumstances, can only be expected to be found either in the other cored boreholes (AD 1/68 and PA 1/68), both of which are proximally sited, or in outcrop, most of which also expose proximal facies. Below this level, from 3 356 to 3 420 ft (1 022.9 to 1 046.9 m), foraminifera are absent. At 3 420 ft, the first massive red and green claystones occur. Top of the Kirkwood Formation is taken at 3 373 ft (1 028.3 m). In all other boreholes the top of the Kirkwood Formation is taken as first down-hole appearance of red (and minor green) claystone lithologies.

### OUTCROP/SUBCROP MAP OF THE SUNDAYS RIVER FORMATION

Figure 3 illustrates the outcrop and subcrop beneath the upper Algoa Group of the Sundays River Formation, based on the biozones recognized in the top-hole portions of the boreholes, together with the outcrops, and reflecting the major structural features of the basin. The widespread minor faulting throughout the Sundays River Formation succession clearly renders this a generalization.

### BIOZONES, FACIES AND TIME LINES

Some comment is necessary on the chronostratigraphic value of the biozones proposed above. Examination of many Pletmos, Gamtoos and offshore Algoa borehole sections has shown that this biozonation of the Sundays River Formation can be used in the parts of these three basins that accumulated under normal marine, continental-shelf conditions. The biozonation begins to fail in marginal marine and estuarine environments, and with increasing distance down the continental slope. In addition, regions affected by substantial freshwater and sediment input off river mouths, even though perhaps at a middle-shelf water depth, or where poorly oxygenated conditions prevailed, tend to have supported insufficient diversity of foraminifera for the biozonation to be effective. The only biozone that is an exception is, clearly, the lowest—Biozone D, distinguished by *Miliammina latrobei* sp. nov.

In general, the foraminifera results compare with those of the ostracod studies (Brenner & Oertli 1976; Valicenti & Stephens 1984), as shown in Figure 5, but the precise relationships of the various ostracod and foraminifera biozones remain to be determined. Close similarities in the electric log correlation and foraminifera biozonation also affirm the basic synchronicity of the biozonation presented herein (Fig. 7). Concern for a comparison of results in this way is necessary to establish conclusively that the foraminifera (and ostracod, palynological and ammonite) zones reflect synchronous events. It is clear, from the distribution of the foraminifera biozones recognized so far in the Late Valanginian and Hauterivian of the Pletmos, Gamtoos and Algoa basins, that they are probably more-or-less synchronous in the areas of these basins where



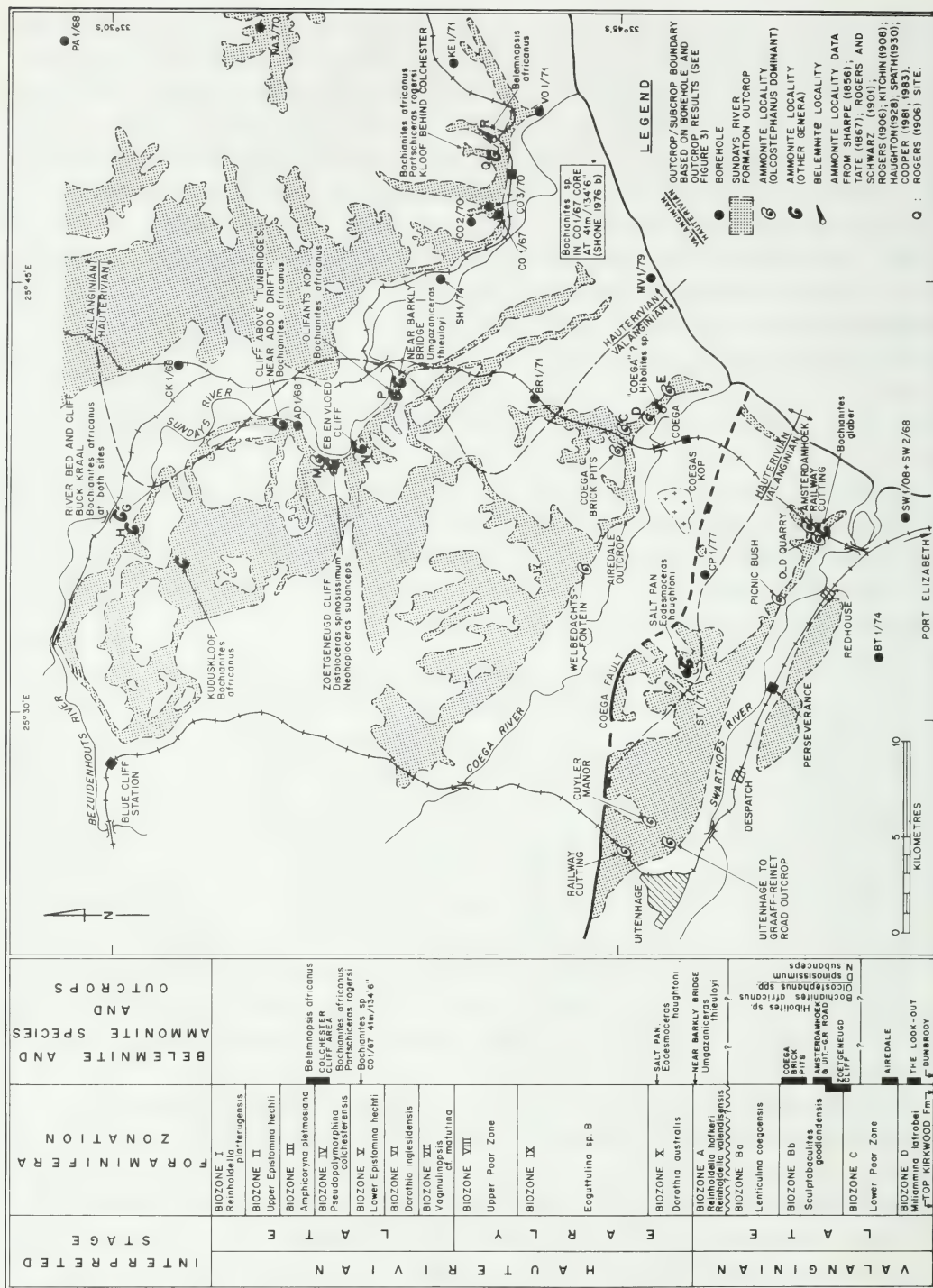


Figure 11.

Distribution of ammonites in outcrops and borehole cores of the Sundays River Formation and suggested correlation with the foraminifera-based interval biozonation.

continental-shelf sedimentation occurred throughout the time period. Inconsistent errors between, for example, the foraminifera and ostracod biozonations are more likely to be due to variations in sampling, processing, sieving and picking each sample studied.

### AMMONITE CONTROL

Ammonites have been widely reported from the Sundays River Formation since the earliest days, but their potential stratigraphic value has been somewhat clouded by the frequent lack of detailed collecting-site data. Ammonite faunas were described primarily by Sharpe (1856), Tate (1867), Kitchin (1908), Spath (1930), and in particular detail by Cooper (1981, 1983); all later authors commented on the dominance of the genus *Olcostephanus* and the relative sparsity of other forms. Cooper (1981, 1983) recognized 23 ammonite species or varieties, one belemnite and one nautiloid. Of the ammonites, 15 are referable to *Olcostephanus* and indicate a Late Valanginian age. Despite their presence in outcrops, no ammonites or belemnites (as microscopic fragments occurring in association with the microfaunas) have been found in the core, cutting or outcrop samples of this study.

Since ammonites have been reported from several of the outcrops studied for foraminifera and reported on in the present work, some attempt is made here to correlate known ammonite assemblages with known foraminifera assemblages, as detailed in Figure 11. As can be seen, most of the outcrops bearing ammonites expose the lower portions of the Sundays River Formation, of Late Valanginian age, particularly within Biozones Ba, Bb and possibly C. The only ammonite finds from outcrops exposing higher stratigraphic levels are: (1) the *Eodesmoceras haughtoni* Spath specimen from Salt Pan, adjacent to borehole ST 1/71 site; and (2) the *Bochianites africanus* (Tate) and *Partschiceras rogersi* (Kitchin) specimens from the kloof behind Colchester (Site Q of Rogers 1906) and, in the case of the former species, from two adjacent sites, all in the vicinity of boreholes VO 1/71, KE 1/71 and the three CO holes. These occurrences of ammonites, on the basis of the foraminifera studies presented here, are regarded as Early Hauterivian (Salt Pan) and Late Hauterivian (kloof behind Colchester and adjacent sites), respectively. In addition, Shone (1976b: 23) reported the presence of *Bochianites* sp. at 41 m (134 ft 6 in) in the cored section of borehole CO 1/67 (Late Hauterivian Biozone V on the basis of the foraminifera). The apparent record of *Rogersites* (otherwise *Olcostephanus*) at 360 ft (109.7 m) in the CO 1/67 cores by Rigassi (1968: 11, 13, 16) seems questionable, given the large size of most *Olcostephanus* specimens as against the 3.5 inch top-hole core diameter, and the unlikely chance of a major part of the ammonite(s) being recovered within the encompass of the core diameter. The record of *Olcostephanus* (as *Rogersites*) *atherstoni* (Sharpe) by Engelbrecht *et al.* (1962: 16) from Vetmaak Vlakte (presumably Colchester Cliff), reported by unknown earlier authors, is the only other occurrence of this genus from high in the Sundays River sequence, and it must be regarded with some suspicion since it appears not to have been corroborated by later work.

The ages interpreted from the ammonites from higher in the section seem to

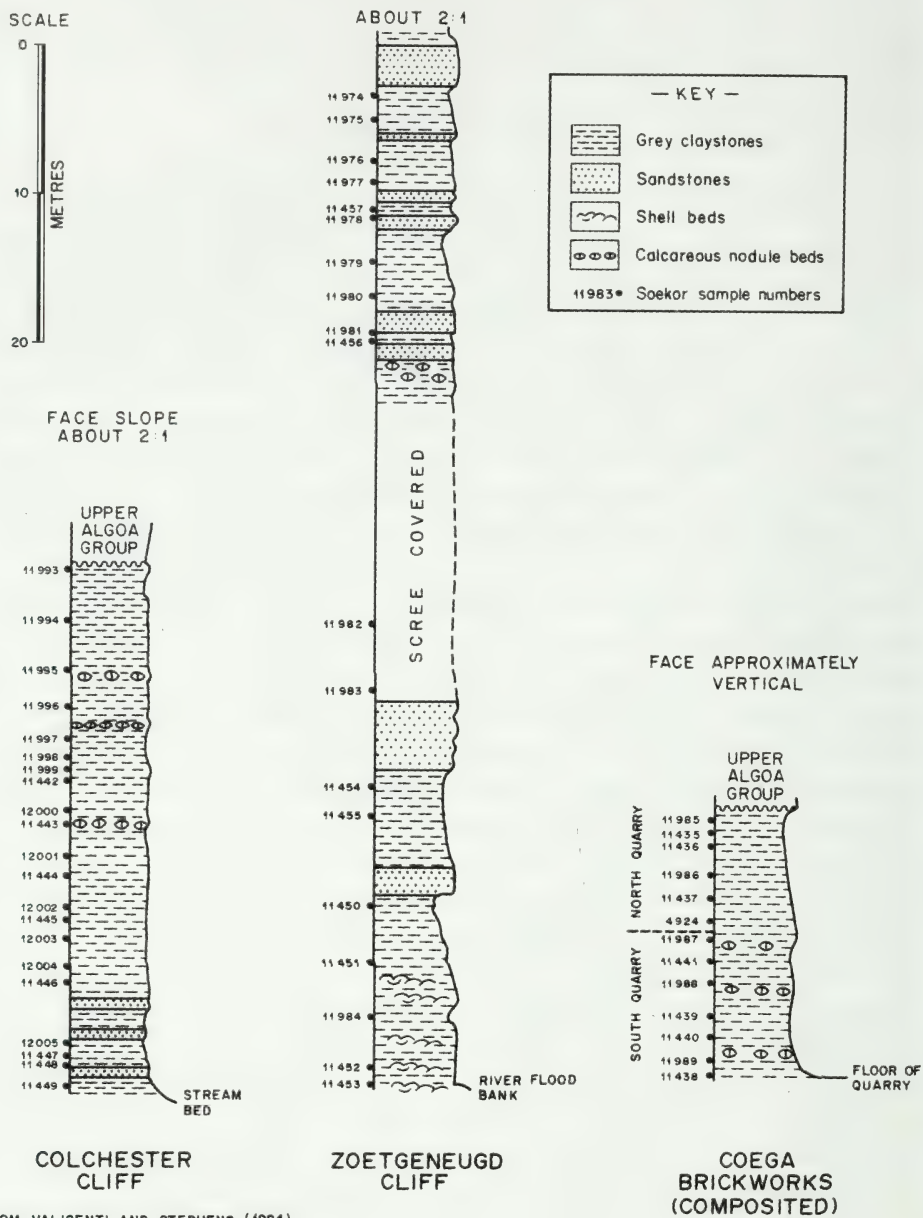


Figure 12.

Lithologies and levels of studied samples of three outcrops:  
Coega Brick Pits, Colchester Cliff and Zoetgeneugd Cliff.



accommodate the ages gained from the foraminifera. *Partschiceras rogersi* is also known from the Early Valanginian and Early Hauterivian of Madagascar, and Cooper (1981) concluded that it was a relatively long-ranging species. In the case of *Bochianites africanus*, the genus is regarded as ranging from the Portlandian to the Hauterivian, and too little is known from elsewhere of the stratigraphic range of the species (Cooper 1981). *Eodesmoceras haughtoni* is referred to a genus with two subgenera that are not clearly distinguished: *E. (Eodesmoceras)* ranging from Valanginian to Early Hauterivian and *E. (Miodesmoceras)* typical of the Barremian (Cooper 1981).

#### FORAMINIFERAL BIOSTRATIGRAPHY OF THE VALANGINIAN AND HAUTERIVIAN OF THE SOUTHERN CAPE

Figure 8 correlates the foraminifera biozonation of the Sundays River Formation proposed here with those of Pletmos Basin borehole PB-A1, the Brenton Formation and the Mngazana Formation. Re-examination of offshore borehole PB-A1 (originally detailed by McLachlan *et al.* 1976b), following extensive re-processing of samples in the late 1970s, showed the first indications that a very similar foraminifera zonation could be constructed for the proximal parts of both the Pletmos and Algoa Basins. Later work has extended this biozonation to the offshore Gamtoos Basin, where a similar section (boreholes Ha-F1 and Ha-N1) occurs, although onshore there the sequence is essentially non-marine (boreholes LO 1/69 and MK 1/70).

The marine beds outcropping at Brenton are correlated to PB-A1 borehole on the presence of *Astacolus beerae* Brenner & McMillan at both localities, a species that is confined to a thin interval immediately overlying red and green, non-marine beds at PB-A1, and has been taken to be an approximate equivalent of Biozone D of the Sundays River Formation. The relatively early age of the Brenton Formation is confirmed too by the absence of *Lenticulina coegaensis* sp. nov., a species that ranges down to the base of Biozone B or Bb in both PB-A1 and in the Algoa Basin boreholes.

In the case of Mngazana, the presence of *Lenticulina coegaensis* sp. nov. (as *Lenticulina bifurcilla* Bartenstein & Brand) indicates a Biozone B age, slightly later than the Brenton Formation. Other species, such as the large, rather compressed and many chambered test of *Lenticulina nodosa* (Reuss) (McLachlan *et al.* 1976a, fig. 16 (no. 18)) and *Lagena* cf. *sulcata* (Walker & Jacob) (the Mngazana form) are typical of Late Valanginian, and Berriasian to early Late Valanginian rocks, respectively. The Mngazana outcrop is here regarded as being referable to the earlier part of Biozone B, although it may possibly be of latest Biozone B age (just later than the 1At1 unconformity).

The reprocessing and re-study of borehole PB-A1 has revealed a much more distinctive and diverse foraminifera fauna in the lower marine unit (Colchester Member equivalent) than was first reported by McLachlan *et al.* (1976b). The foraminifera assemblages of this unit show some comparison with those of the Colchester Member of the Uitenhage Trough, Algoa Basin, and both are regarded as Portlandian in age on the basis of their contained foraminifera.

## THE ALGOA BASIN OUTCROPS

Samples studied from Amsterdamhoek, Coega Brick Pits, Colchester Cliff, Uitenhage to Graaff-Reinet Road, and Zoetgeneugd Cliff are the same as those studied for Ostracoda by Valicenti & Stephens (1984). The levels of samples studied from Coega Brick Pits, Colchester Cliff and Zoetgeneugd Cliff are shown in Figure 12. Samples studied are listed in Table 3.

*Airedale*

The Airedale exposures lie close to outcropping Kirkwood Formation red beds on the north side of the Coega River valley. Samples were collected by I. R. McLachlan. Microfaunas are poor in all four samples studied (Fig. 13). The assemblages are referred to the Late Valanginian Biozone C because of the poor faunas and the proximity of the locality to the red beds. The microfauna recovered so far is not conclusive enough to confirm this placing. *Olcostephanus*-dominated ammonite assemblages have been recovered from localities around Coega, to the south-east, and at Welbedachtsfontein (Haughton 1928; Spath 1930; Cooper 1981) to the north-west, both of which are approximately along strike to the Airedale site. There is some indication that the basal marine beds on Welbedachtsfontein contain *Olcostephanus species* (Haughton 1928: 27; Spath 1930).

*Amsterdamhoek*

Five samples collected by I. R. McLachlan from the Amsterdamhoek railway cutting provided a diverse and abundant foraminifera fauna (Fig. 14). About 18 m of section is

	<i>Lenticulina nodosa</i> s.l.	<i>Haplophragmoides</i> spp.	<i>Ammobaculites</i> spp.	? <i>Sculptobaculites goodlandensis</i>	
4920	○	⊙	⊙	○	4920
4921	—	—	—	—	4921
4922	—	—	—	—	4922
4923	—	—	—	—	4923
4923.1	—	—	—	—	4923.1
Key to symbols/No. of specimens					
○ 1-2   ⊙ 3-5   ⊙ 6-15   ● 16-49					
● 50+					

Figure 13.

Distribution of foraminifera in Airedale outcrops.

exposed at the sampled site, but Shone (1976*b*) recorded a total of some 70 m of section. Tankard *et al.* (1982, fig. 12.4, section 4), basing their section on work by Shone (1976*b*), show the exposure to be composed predominantly of claystones, with minor, usually thin sandstones, that in part show coarsening upward cycles. The abundance of *Epistomina caracolla* (Roemer) s.l., with *Reinholdella hofkeri* (Bartenstein & Brand) in the basal sample and *Sculptobaculites goodlandensis* (Cushman & Alexander) near the top of the section, indicates that the exposure is probably all of Biozone Bb age, Late Valanginian. Calcareous foraminifera are rare in the highest sample studied, and it seems likely that some leaching has occurred here.

Ammonites from the Amsterdamhoek railway cutting and vicinity are primarily of *Olcostephanus* species (Rogers & Schwarz 1901; Rogers 1906; Kitchin 1908; Cooper 1981), and emphasize the Late Valanginian age. *Reinholdella hofkeri* (as *Conorboides*) was previously recognized from this locality (Rigassi 1968, pl. 12).

### *Coega Brick Pits*

Thirteen samples were collected by I. R. McLachlan and C. Reabow. The samples derive from adjacent quarries, termed North Quarry and South Quarry by I. R. McLachlan, located just west of the railway line and about 3.5 km north of Coega Station. The section shown by Valicenti & Stephens (1984) and reproduced here (Fig. 12) is a composite of the two quarry sections. A total of about 18 m of Cretaceous section is exposed, the upper half in North Quarry, the lower half in South Quarry. Foraminifera faunas are generally abundant and diverse, although three samples provided only poor faunas. One of these, the highest sample collected, is probably leached, as it derives from a short distance below the Sundays River/upper Algoa Group boundary unconformity. The entire section is referable to Biozone Bb of the Late Valanginian (*Sculptobaculites goodlandensis* biozone). Results of studying the Coega Brick Pits samples are shown in Figure 15.

*Olcostephanus* species predominate in ammonite collections made at Coega Brick Pits and surrounding localities, reinforcing the Late Valanginian age interpretation. There is some indication that the basal marine beds in the Coega area contain 'numerous specimens' of *Olcostephanus* (Haughton 1928: 27).

### *Colchester Cliff*

The small valley (or kloof) in the substantial cliff just north-east of Colchester railway halt (near to Rogers 1906, Site Q) in the lower Sundays River valley yielded variable faunas from 21 samples collected by I. R. McLachlan and C. Reabow. The majority of the Colchester Cliff section is obscured by scree and soil. The exposed sequence in the kloof appears to be extensively leached, which is unfortunate since this is the only major outcrop studied in the Hauterivian part of the Sundays River Formation. Agglutinated foraminifera predominate in most of the samples, and in all cases pyrite is oxidized. Only in a few samples do calcareous species occur, the most frequent of which is *Pseudopolymorphina colchesterensis* sp. nov. Some spherical Radiolaria are present. Results are shown in Figure 16. The outcrop is probably mostly referable to Late Hauterivian Biozone IV, but the latest Biozone V may occur near the base. Borehole CO 2/70, drilled



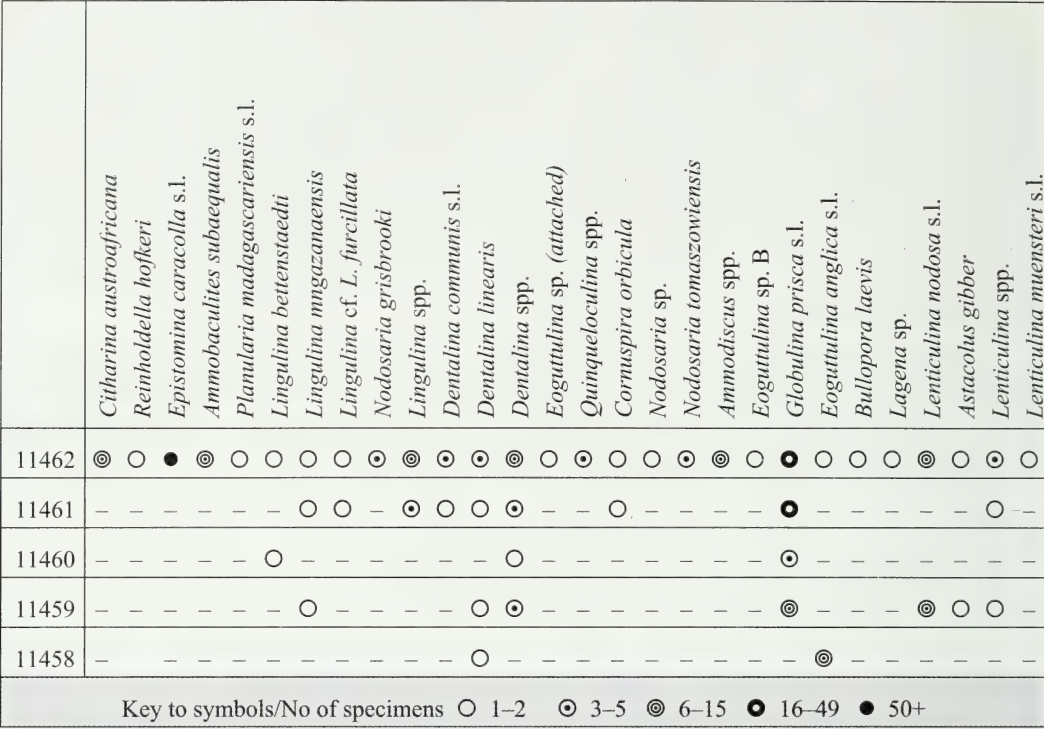


Figure 14.  
Distribution of foraminifera in Amsterdamhoek railway-cutting outcrop.

to the north-west of the sampled outcrop, on top of the Colchester Cliff, also intersected Biozone IV, and perhaps the basal Biozone III, in the topmost Sundays River Formation. The section studied for foraminifera is about the same locality from which the ammonites *Partschiceras rogersi* (Kitchin) and *Bochianites africanus* (Tate) (Rogers 1906; Kitchin 1908; Cooper 1981) derive.

Dunbrody area

In the vicinity of the confluence of the Bezuidenhouts and Sundays rivers in the northernmost Algoa Basin are a number of outcrops sited across and close to the boundary of the Kirkwood and Sundays River formations. Details of these sites are given in McLachlan & McMillan (1976, fig. 7). At the time of that publication, it was believed that these outcrops, mostly of marginal marine deposits, were referable to the Colchester Member, which was considered to outcrop and subcrop beneath the Sundays River Formation in the Dunbrody area (McLachlan & McMillan 1976, fig. 9). However, the absence of any identifiable Colchester Member in any of the northernmost Algoa boreholes (AD 1/68, CK 1/68, NA 1/69, NA 2/70, NA 3/70 and PA 1/68), and the lack of any marine fossils in the Colchester Member of the Sundays River Trough would appear to preclude such an interpretation. The Colchester Member in the Sundays River Trough is now regarded as extending no further north than the Barkly Bridge area, and it is

<i>Astacolus explicatus</i> s.l.	<i>Astacolus calliopsis</i> s.l.	<i>Astacolus</i> spp.	<i>Trochammina</i> spp.	? <i>Dorothia</i> sp.	<i>Amnoglobigerina</i> cf. <i>A. globigeriniformis</i>	<i>Haplophragmoides</i> sp.B	<i>Haplophragmoides</i> sp.C	<i>Haplophragmoides</i> sp.A	<i>Haplophragmoides</i> spp.	<i>Ammobaculites</i> sp. B	<i>Ammobaculites</i> spp.	<i>Ammobaculites</i> sp. A	<i>Dorothia australis</i>	<i>Tristix acutangula</i>	<i>Lingulina simplicissima</i>	? <i>Frondicularia</i> sp.	? <i>Gaudryinella</i> sp.	<i>Comspira</i> sp.	<i>Ammobaculites</i> sp. G	<i>Miliammina</i> sp.	? <i>Textularia zoetogeneugdia</i>	<i>Eoguttulina</i> cf. <i>E. liassica</i>	? <i>Ramulina</i> sp.	<i>Sculptobaculites goodlandensis</i>	<i>Vaginulina</i> spp.	? <i>Lingulina</i> sp.	? <i>Saccammina</i> sp.	
○	⊙	⊙	⊙	⊙	⊙	●	⊙	⊙	●	⊙	●	○	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11462
-	-	○	-	⊙	-	-	○	-	●	⊙	⊙	-	○	○	○	○	○	⊙	○	-	-	-	-	-	-	-	-	11461
-	-	-	○	⊙	⊙	⊙	-	-	●	-	●	-	-	-	-	-	-	-	-	○	⊙	-	-	-	-	-	-	11460
○	⊙	⊙	-	●	●	⊙	⊙	●	●	-	●	⊙	-	-	-	-	○	-	⊙	-	-	⊙	○	○	○	-	-	11459
-	-	-	-	-	○	⊙	○	⊙	●	-	⊙	-	-	-	-	-	-	○	-	-	-	-	-	-	-	○	○	11458
Key to symbols/No of specimens ○ 1-2 ⊙ 3-5 ⊙ 6-15 ● 16-49 ● 50+																												

Figure 14 (CONTINUED).

probably bounded on its northern and eastern sides by the Colchester Fault (see Figs 1 and 2). The oyster beds and grey claystones and sandstones of the Dunbrody area are thus referred to the basal Sundays River Formation, in keeping with the interpretation of the boundary recognized by Haughton (1928). Unfortunately, foraminifera evidence to confirm this interpretation is sadly lacking: nearly all of the samples studied from the Dunbrody area are devoid of foraminifera. Localities sampled by I. R. McLachlan during the 1970s include Dunbrody Bridge (Site 13), Paaltjieskraal (Site 4), Zoutklip (Site 5), Bezuidenhouts River (west of Site 10), Blue Cliff Station (Site 2), Dunbrody Station (Site 10), and Mfuleni (Site 15). Productive samples with foraminifera (two only) are shown in Figure 17. No ammonites have been reported from any of these outcrops.

### *The Look Out area*

Downstream from the Dunbrody area, along the Sundays River at The Look Out, occur the first beds with diverse and abundant marine macrofauna (Site 14 on fig. 7—McLachlan & McMillan 1976). Ten samples were collected by I. R. McLachlan from The Look Out cliff proper, one from the first low-level bridge 0.5 km upstream from The Look Out, and one sample from Castle Cliff, 0.5 km further upstream. The ten samples from The Look Out derive from the same site as that detailed in a vertical section (RS 112) by Shone (1976*b*, fig. 5), but precise positioning of our samples against the vertical section

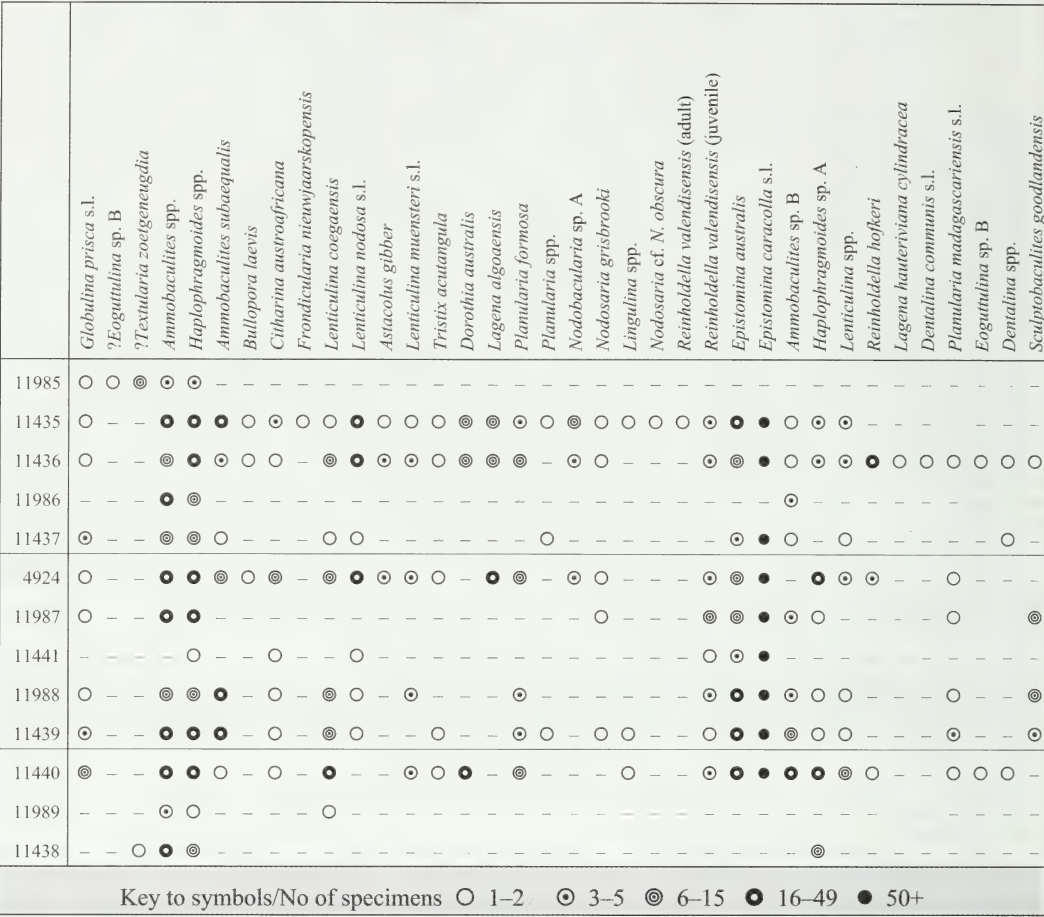


Figure 15.  
Distribution of foraminifera at Coega Brick Pits.

has not proved possible. Despite the diverse and abundant macrofauna at The Look Out cliff, only rare tests of *Miliammina latrobei* sp. nov. were found, and it may be that leaching of the outcrop has occurred. A small, very distinctive, exclusively agglutinated foraminifera assemblage characterized by *Plectinella castlecliffensis* sp. nov. occurs at the low-level bridge outcrop. The presence of *M. latrobei* sp. nov. here too again suggests hyposaline conditions of deposition prevailed. Rare agglutinated foraminifera (*Haplophragmoides* sp., ?*Ammobaculites* sp.) with crinoid ossicles and blocks of *Inoceramus* prisms were found in the sample from Castle Cliff. Results are shown in Figure 18.

Ammonites have not been found in The Look Out area, but occur some 4 km downstream on Summerville Estate (Buck Kraal) where *Bochianites africanus* (Tate) has been reported (Rogers 1906—sites G, H; Cooper 1981).

Uitenhage to Graaff-Reinet Road

A number of exposures were cut into the basal Sundays River Formation near the town



[illegible]

of Uitenhage during the late 1970s, in the reconstruction of the main road north to Graaff-Reinet. These outcrops lie near to the westernmost limit of the Sundays River Formation in the Uitenhage Trough. Red Kirkwood Formation claystones are exposed just to the south near to sample 11463; and again to the west, a little north of Uitenhage town. Red claystones also outcrop a short distance to the north, on the upthrown side of the Coega Fault. Samples studied derive from the basal Sundays River Formation, and were collected by I. R. McLachlan.

From the presence of large numbers of *Epistomina caracolla* (Roemer) s.l. and a few examples of *Lenticulina coegaensis* sp. nov. in sample 11464, this sample must be referable to Late Valanginian Biozone Bb at oldest. The basal Sundays River Formation sample 11463 is probably referable to Biozone C: it contains echinoid shell, but no foraminifera. The stratigraphically higher samples 11465 and 11466 contain *Sculptobaculites goodlandensis* (Cushman & Alexander) and thus are probably also of Biozone Bb age. Results are shown in Figure 19. Sample 11464 proved to be unique in all of the Sundays

	<i>Ammobaculites</i> sp. B	<i>Ammobaculites</i> sp. C	<i>Ammoglobigerina</i> cf. <i>A. globigeriniformis</i>	<i>Globulina prisca</i> s.l.	<i>Haplophragmoides</i> sp. B	<i>Haplophragmoides</i> sp. C	<i>Haplophragmoides</i> sp. D	<i>Haplophragmoides</i> spp.	<i>Pseudopolymorphina colchesterensis</i>	<i>Trochammina</i> cf. <i>T. inflata</i>	<i>Trochammina sundaysriverensis</i>	<i>Amphicoryna plemstosiana</i>	<i>Astacolus explicatus</i> s.l.	<i>Astacolus gibber</i>	<i>Lenticulina nodosa</i> s.l.	? <i>Saccamina</i> spp.	<i>Ammobaculites</i> spp.	<i>Ammobaculites subaequalis</i>	<i>Dorothia</i> sp. A	<i>Eoguttulina anglica</i> s.l.	<i>Ammobaculites parvispira</i>	<i>Dentalina communis</i> s.l.	<i>Eoguttulina</i> cf. <i>E. inovroclaviensis</i>	<i>Lingulina</i> cf. <i>L. furcillata</i>	<i>Lingulina mingazanaensis</i>	<i>Lingulina simplicissima</i>	<i>Reophax</i> spp.	<i>Trochammina</i> spp.	<i>Verneulina secreta</i>	<i>Cornuspira orbicula</i>	<i>Lingulodonsaria nodosaria</i>	<i>Epistomina caracolla</i> s.l.	<i>Lagena</i> 'laevis'	<i>Lenticulina</i> spp.	<i>Vaginulina</i> spp.	<i>Dentalina linearis</i>		
11993	⊙	●	⊙	○	○	○	⊙	●	○	○	○	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11994	-	-	-	-	○	○	-	-	●	-	-	○	○	○	○	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11995	○	⊙	○	-	●	-	-	⊙	-	⊙	○	-	-	-	-	⊙	○	○	○	○	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11996	●	●	○	⊙	●	○	-	⊙	-	●	-	-	-	-	-	-	●	-	○	-	●	○	○	○	○	○	○	○	⊙	○	-	-	-	-	-	-	-	-
11997	-	-	-	○	○	-	-	○	-	○	-	-	-	-	-	-	○	-	-	-	-	○	○	○	-	-	-	○	-	-	-	-	-	-	-	-	-	-
11998	⊙	○	-	-	○	-	○	○	-	○	-	-	-	-	-	-	○	-	○	-	-	-	-	-	-	-	-	-	-	-	○	○	-	-	-	-	-	
11999	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
11442	⊙	○	-	○	○	○	-	○	-	-	-	-	-	-	-	-	○	-	○	-	-	-	-	-	-	-	-	-	-	-	○	⊙	○	○	○	○	-	
12000	●	⊙	○	⊙	●	⊙	-	●	-	⊙	-	-	-	-	-	-	○	-	○	-	-	-	-	-	-	-	○	-	○	-	-	-	-	-	-	-	-	○
11443	●	○	-	○	●	⊙	○	○	-	⊙	-	-	-	-	-	-	⊙	-	○	-	-	○	-	-	-	-	-	-	-	○	-	○	-	-	-	-	-	-
12001	●	●	○	●	●	⊙	○	○	●	○	-	-	⊙	⊙	●	-	●	⊙	-	⊙	-	○	○	○	-	-	○	-	○	-	○	-	●	-	○	○	○	○
11444	⊙	○	○	⊙	⊙	○	○	○	●	○	-	-	○	○	●	-	○	○	-	⊙	-	○	-	-	-	-	-	-	-	-	○	-	○	-	○	-	-	-
12002	●	⊙	○	○	●	⊙	-	●	○	○	-	○	-	○	-	-	●	⊙	⊙	-	○	-	-	-	-	-	○	○	-	-	-	-	-	-	-	-	-	-
11445	●	⊙	○	-	●	⊙	-	●	-	○	-	-	-	-	-	-	⊙	○	○	-	○	-	-	-	-	-	-	⊙	-	-	-	-	-	-	-	-	-	-
12003	●	○	⊙	-	●	-	-	○	-	○	-	-	-	-	-	-	●	⊙	-	-	○	○	-	-	-	-	-	●	-	-	-	-	-	-	-	-	-	-
12004	●	○	○	○	○	○	-	○	-	⊙	-	-	-	-	-	-	○	●	⊙	-	○	-	-	-	-	-	●	-	-	-	-	-	-	-	-	-	-	
11446	●	○	○	-	●	○	○	●	-	⊙	-	-	-	-	-	-	○	-	⊙	-	-	-	-	-	-	●	-	-	-	-	-	-	-	-	-	○	-	
12005	●	○	○	○	●	-	○	○	-	○	-	-	-	-	-	○	●	-	⊙	-	○	-	-	-	-	●	-	○	-	-	-	-	-	-	-	-	-	
11447	○	○	-	⊙	○	-	-	○	-	-	-	-	⊙	⊙	●	-	⊙	●	○	⊙	-	⊙	-	-	-	○	-	○	-	-	-	○	○	-	○	○	○	
11448	○	⊙	-	○	○	○	○	●	-	-	-	-	-	-	-	-	⊙	○	-	○	-	-	-	-	○	○	-	-	-	-	-	-	-	-	-	-	-	-
11449	○	○	-	-	○	○	-	○	-	-	-	-	-	-	-	-	●	-	-	-	-	-	-	-	-	-	-	○	-	-	-	-	-	-	-	-	-	-
Key to symbols/No of specimens ○ 1-2 ⊙ 3-5 ⊙ 6-15 ● 16-49 ● 50+																																						

Key to symbols/No of specimens ○ 1-2 ⊙ 3-5 ⊙ 6-15 ● 16-49 ● 50+

Figure 16.

Distribution of foraminifera in the kloof, eastern end of the Colchester Cliff (near site Q of Rogers (1906)).

River Formation samples studied in this project because of its unusually high numbers of simple miliolid tests of *Vinelloidea buchenroderi* sp. nov. and *Nodobacularia* sp. A. These, with *Bullopore laevis* (Sollas) and some indeterminate attached agglutinated forms, clearly indicate an environment influenced by highly oxygenated and turbulent waters in a littoral or sub-littoral setting.

Ammonite assemblages collected from the railway cutting north of Uitenhage (Rogers

	<i>Eoguttulina</i> cf. <i>E. liassica</i>	<i>Gravellina</i> sp. <i>A</i>	<i>Lingulina</i> sp.	<i>Astacolus calliopsis</i> s.l.	<i>Astacolus schloenbachi</i>	<i>Citharina austroafricana</i>	<i>Haplophragmoides</i> sp. <i>A</i>	<i>Lenticulina subtilis</i>	<i>Lenticulina meunsteri</i> s.l.	<i>Lingulina trilobita</i>	<i>Nodosaria</i> sp. <i>A</i>	<i>Nodosaria tomaszowiensis</i>	<i>Nubecularia lucifuga</i>	<i>Planularia formosa</i>	<i>Planularia madagascariensis</i> s.l.	<i>Pravoslavlevia</i> cf. <i>P. tsaramandrosoensis</i>	<i>Pravoslavlevia franki</i>	<i>Pravoslavlevia pravoslavlevi</i>	<i>Pseudonodosaria humilis</i>	<i>Ramulina</i> sp.	<i>Reinholdella</i> sp. <i>D</i>	<i>Tristix excavata</i>	<i>Vaginulinopsis</i> cf. <i>V. prima</i>	<i>Ammobaculites</i> sp. <i>A</i>	<i>Tristix acutangula</i>	<i>Ammodiscus</i> sp.	<i>Lenticulina heiermanni</i>	<i>Gaudryinella alexandria</i>	<i>?Dorothia inglesidensis</i>	<i>?Gaudryinella alexandria</i>	<i>Bullopore laevis</i>	<i>Dentalina</i> sp.	<i>?Dorothia</i> sp. <i>A</i>			
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11993	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11994	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11995	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11996	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11997	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11998	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11999	
○	○	○	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11442	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12000	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11443	
○	-	-	●	⊙	⊙	⊙	⊙	○	●	○	○	○	⊙	○	⊙	○	⊙	○	○	○	○	○	○	-	○	-	-	-	-	-	-	-	-	-	12001	
-	-	-	○	○	-	-	-	⊙	⊙	-	-	-	-	-	-	-	-	-	-	-	-	-	-	○	○	-	-	-	-	-	-	-	-	-	-	11444
○	-	-	-	-	-	-	⊙	-	-	-	-	-	-	-	-	-	○	-	-	-	-	-	-	-	○	○	-	-	-	-	-	-	-	-	-	12002
-	-	-	-	-	-	-	⊙	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	○	-	-	-	-	-	-	-	11445
-	-	-	-	-	-	-	●	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	⊙	-	-	-	-	-	-	-	-	-	-	-	-	12003
○	-	-	-	-	-	-	●	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	⊙	-	-	-	-	-	-	○	-	-	-	-	-	12004
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	⊙	-	-	-	-	-	○	-	-	-	-	-	11446
-	-	-	-	-	-	-	●	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	○	-	-	-	-	-	12005
-	-	-	●	○	⊙	⊙	-	⊙	-	-	-	-	○	-	○	-	○	○	-	-	-	-	-	-	-	-	-	-	-	-	-	○	○	-	-	11447
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	○	-	-	11448
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11449
Key to symbols/No of specimens ○ 1-2 ⊙ 3-5 ⊙ 6-15 ● 16-49 ● 50+																																				

& Schwarz 1901) and from the vicinity of Cuyler Manor, east of Uitenhage (Rogers & Schwarz 1901; Haughton 1928; Spath 1930) are dominated by *Olcostephanus* species (Cooper 1981) and again emphasize the Late Valanginian age of the samples studied for foraminifera. There is some suggestion by Haughton (1928: 27) that the basal marine beds on Cuyler Manor, east of Uitenhage, contain *Olcostephanus* species.



	<i>Haplophragmoides</i> sp.	<i>?Lingulina mngazanaensis</i>	<i>Ammobaculites</i> sp.	
11468	○	○		11468
11471		-	○	11471
Key to symbols/No of specimens ○ 1-2				

Figure 17.  
Distribution of foraminifera in the marine beds near Dunbrody Bridge (site 13). All other samples from the Dunbrody area proved devoid of foraminifera.

	<i>Ammobaculites</i> sp.	<i>Ammobaculites</i> sp. B	<i>Haplophragmoides</i> spp.	<i>Miliammina latrobei</i>	<i>Plectinella castelcelfensis</i>	<i>?Ammobaculites</i> spp.	<i>Globulina prisca</i>	<i>Pyrulina cylindroides</i>	<i>Trochammina</i> spp.	<i>?Glomospira</i> sp.	<i>?Miliammina latrobei</i>	<i>?Ammomarginulina</i> sp.	
18588	○	○	○	-	-	-	-	-	-	-	-	-	18588
18589	-	-	-	●	○	◎	○	○	◎	○	-	-	18589
18590	-	-	-	◎	-	-	○	-	-	-	-	○	18590
18591	-	-	-	-	-	-	-	-	-	-	-	-	18591
18592	-	-	○	-	-	-	-	-	-	-	○	-	18592
18593	-	-	-	-	-	-	-	-	-	-	-	-	18593
18594	-	-	-	-	-	-	-	-	-	-	-	-	18594
18595	-	-	-	-	-	-	-	-	-	-	-	-	18595
18596	-	-	-	-	-	-	-	-	-	-	-	-	18596
18597	-	-	-	-	-	-	-	-	-	-	-	-	18597
18598	-	-	-	-	-	-	○	-	-	-	-	-	18598
18599	-	-	-	-	-	-	-	-	-	-	-	-	18599
Key to symbols/No of specimens ○ 1-2 ◎ 3-5 ◎ 6-15 ● 16-49 ● 50+													

Figure 18.  
Distribution of foraminifera at sites in the Look Out area.

Zoetgeneugd Cliff

Samples were collected by I. R. McLachlan and C. Reabow. This extensive outcrop, cut by the Sundays River, is the surface stratotype for the Sundays River Formation. The section exposes interbedded sandstones, siltstones and claystones, with the sandstones showing coarsening up, and more rarely, fining up features (Tankard *et al.* 1982, fig. 12.4, section 3). The studied section, examined also for ostracods by Valicenti & Stephens (1984) is from the northern end of the outcrop, and is not as complete a section as exposed in the highest cliffs a little to the south. Samples studied have yielded rather variable

foraminifera faunas. This is due in part to post-depositional leaching of the exposure, and in part to the rather silty and sandy lithologies that dominate the section. However, the abundance and diversity of foraminifera low in the outcrop (sample 11450), and the presence here of *Epistomina caracolla* (Roemer) s.l. and *Reinholdella valendisensis* (Bartenstein & Brand), with scattered *Sculptobaculites goodlandensis* (Cushman & Alexander) higher in the section, would suggest that the majority of the exposure is referable to Biozone Bb. The basal part of the outcrop is probably of Biozone C age. Results are given in Figure 20.

Ammonites from the Zoetgeneugd and Eb en Vloed cliffs (Rogers 1906) are again principally referable to *Olcostephanus* (Cooper 1981), and imply a Late Valanginian age. This locality was one of the earliest exposures of the Sundays River Formation recognized (see Atherstone 1857: 531) and it seems probable that most nineteenth-century records of fossils from the 'Sundays River' were obtained from the Zoetgeneugd and Eb en Vloed cliff-line. The outcrops lie 2 km to the south-west of borehole AD 1/68, where only some 200 m of the basal Sundays River Formation was intersected, and just to the east of Kirkwood Formation outcrops on the farm Coega Kammas Kloof, as well as being athwart the Addo Nose basement high, thus confirming the very low stratigraphic level of the Sundays River Formation exposed here.

	<i>Haplophragmoides</i> spp. <i>Ammobaculites</i> spp. <i>Ammobaculites subaequalis</i> <i>Bullopore laevis</i> <i>Dorothyia australis</i> <i>Tristix excavata</i> <i>Planularia</i> spp. <i>Planularia formosa</i> <i>Lenticulina coegaensis</i> <i>Lenticulina nodosa</i> s.l. <i>Lenticulina</i> sp. <i>Astacolus</i> sp. <i>Astacolus explicatus</i> s.l. <i>Astacolus gilli</i> <i>Nodosaria grisbrooki</i> <i>Dentalina</i> spp. <i>Vaginulina</i> sp. <i>Lingulina</i> spp. <i>Nodobacularia</i> sp. A <i>Citharina austroafricana</i> <i>Vinelloidea buchenroderi</i> <i>Epistomina australis</i> <i>Epistomina</i> sp. D <i>Epistomina caracolla</i> s.l. <i>Ammobaculites</i> sp. C <i>Ammobaculites parvispira</i> <i>Sculptobaculites goodlandensis</i> <i>Ammobaculites</i> sp. B <i>Haplophragmoides</i> sp. A <i>Haplophragmoides</i> sp. B <i>Ammobaculites</i> sp. A
11463	○ ○ -

Figure 19.

Distribution of foraminifera at three sites along the Uitenhage to Graaff-Reinet Road.

	<i>Ammobaculites</i> spp.	<i>Sculptobaculites goodlandensis</i>	<i>Ammobaculites subaequalis</i>	<i>Ammobaculites</i> sp. A	<i>Ammobaculites</i> sp. B	<i>Haplophragmoides</i> sp. A	<i>Haplophragmoides</i> sp. B	<i>Haplophragmoides</i> sp. G	<i>Trochammina</i> spp.	<i>Haplophragmoides</i> spp.	<i>Trochammina</i> cf. <i>T. inflata</i>	<i>Ammoglobigerina</i> cf. <i>A. globigeriniformis</i>	<i>Eoguttulina anglica</i> s.l.	<i>Planularia formosa</i>	<i>?Protonina</i> sp.	<i>Tritaxis</i> sp.	<i>Lingulina</i> sp.	<i>Citharina austroafricana</i>	<i>Lenticulina nodosa</i> s.l.	<i>?Ammobaculites</i> sp.	<i>Globulina prisca</i> s.l.	<i>?Cyclogyra</i> sp.	<i>Bullopore laevis</i>	<i>Tristix acutangula</i>	<i>Citharina pseudotriatula</i>	<i>Planularia madagascariensis</i> s.l.	<i>Ammodiscus</i> spp.	<i>Epistomina caracolla</i> s.l.	<i>Epistomina australis</i>
11974	○	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11975	●	⊙	○	⊙	⊙	⊙	●	○	⊙	●	○	○	○	○	○	⊙	○	-	-	-	-	-	-	-	-	-	-	-	-
11976	○	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11977	○	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	○	-	-	-	-	-	-	-	-	-	-	-
11457	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	○	○	○	-	-	-	-	-	-	-	-	-
11978	-	-	-	-	-	-	-	○	○	⊙	-	-	○	-	-	-	-	-	-	○	-	-	-	-	-	-	-	-	-
11979	●	⊙	●	-	-	○	-	○	⊙	●	-	○	-	-	-	○	-	-	-	-	-	○	-	-	-	-	-	-	-
11980	○	-	-	-	-	-	-	-	○	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11981	○	-	-	-	-	-	-	-	○	○	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11456	⊙	-	⊙	-	-	-	-	-	○	●	○	○	-	○	-	○	-	○	-	-	-	-	-	-	-	-	-	-	-
11982	○	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11983	-	-	-	-	-	-	-	-	-	-	-	○	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11454	⊙	-	○	-	-	-	-	-	-	○	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11455	⊙	-	-	-	-	-	-	-	-	-	-	-	○	○	-	-	-	○	○	-	-	-	-	-	-	-	-	-	-
11450	●	-	●	⊙	-	●	○	-	⊙	●	⊙	⊙	⊙	○	-	-	-	⊙	○	-	-	-	○	⊙	○	●	○	●	○
11451	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11984	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11452	⊙	-	-	-	-	-	-	-	-	○	-	-	-	○	-	-	-	-	-	○	-	-	-	-	-	-	-	-	-
11453	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Key to symbols/No of specimens ○ 1-2 ⊙ 3-5 ⊙ 6-15 ● 16-49 ● 50+

Figure 20.

Distribution of foraminifera from the northern end of the Zoetgeneugd Cliff, outcrop stratotype of the Sundays River Formation.



[illegible]

Figure 20 (CONTINUED).

TABLE 3  
Localities and descriptions of outcrop samples studied.

<b>Locality: AIREDALE</b> (page 44)	
Latitude: 33°44'34"S	Longitude: 25°35'51"E
Samples collected (SOEKOR Laboratory number and description)	
4920—North quarry next to Coega River: basal Sundays River Formation; sandy pale grey claystone, rare shell, no lignite.	
4921—West quarry (Upper): slightly silty grey claystone with cemented sandstone, no shell, very rare lignite.	
4922—West quarry (Lower): very silty grey claystone, very rare shell and lignite.	
4923—Central quarry: basal Sundays River Formation; very sandy, very pale grey claystone, no shell, no lignite.	
4923.1—Central quarry: red claystones: topmost Kirkwood Formation.	
<b>Locality: AMSTERDAMHOEK</b> First exposure of Sundays River Formation, in railway cutting, 2.5 km north of Swartkops station. (page 44)	
Latitude: 35°50'30"S	Longitude: 25°36'25"E
Samples collected (SOEKOR Laboratory number and description)	
11458—Top: fine grey claystone, no shell, very rare lignite.	
11459—Fine, slightly silty grey claystone, no shell, moderate lignite.	
11460—Fine grey claystone, no shell, some lignite.	
11461—Fine grey claystone, slightly iron-stained, no shell, some lignite.	
11462—Bottom: fine grey claystone, some bivalve shell, no lignite.	
<b>Locality: COEGA BRICK PITS</b> (page 45)	
Latitude: 33°45'15"S	Longitude: 25°40'00"E
Samples collected (SOEKOR Laboratory number and description)	
11985—North Quarry, top: fine grey claystone, no shell or lignite.	
11435—North Quarry: fine dark grey claystone, some lignite, no shell.	
11436—North Quarry, middle: fine dark grey claystone, some shell and rare lignite.	
11986—North Quarry: fine dark grey claystone, no shell or lignite.	
11437—North Quarry, bottom: fine dark grey claystone, some shell and rare lignite.	
4924—North Quarry, bottom: fine silty dark grey claystone, rare shell and lignite.	
11987—South Quarry, top: fine slightly silty grey claystone, very rare shell and lignite.	
11441—South Quarry: very silty grey claystone, very rare lignite, no shell.	
11988—South Quarry: fine dark grey claystone, very rare shell, common lignite.	
11439—South Quarry: fine dark grey claystone, some shell and moderate lignite.	
11440—South Quarry: fine dark grey claystone, rare lignite, no shell.	
11989—South Quarry: very silty grey claystone, no shell, very rare lignite.	
11438—South Quarry, bottom: fine silty dark grey claystone, rare lignite.	

<b>Locality: COLCHESTER CLIFF</b> Near Site Q of Rogers (1906) (page 45)	
Latitude: 33°41'00"S	Longitude: 25°49'35"E
Samples collected (SOEKOR Laboratory number and description)	
11993—Top Sundays River Formation, just below base Upper Algoa Group: fine grey claystone, no shell or lignite.	
11994—Fine grey very silty claystone, no shell or lignite.	
11995—Fine grey claystone, no shell, very rare lignite.	
11996—Fine grey claystone, no shell, rare lignite.	
11997—Fine grey claystone, no shell, very rare lignite.	
11998—Fine grey, silty claystone, no shell, moderate lignite.	
11999—Iron-stained cemented nodular band, no shell or lignite.	
11442—Fine grey, slightly silty claystone, no shell, some lignite.	
12000—Partly iron-stained fine grey claystone, no shell, very rare lignite.	
11443—Fine grey claystone, no shell, very rare lignite.	
12001—Fine grey claystone, slightly shelly and very rare lignite.	
11444—Fine grey claystone, very rare shell and lignite.	
12002—Fine grey claystone, no shell, very rare lignite.	
11445—Fine grey claystone, no shell, very rare lignite.	
12003—Fine grey claystone, partly iron-stained, no shell, very rare lignite.	
12004—Fine grey claystone, no shell.	
11446—Fine grey claystone, no shell, very rare lignite.	
12005—Fine grey claystone, no shell, very rare lignite.	
11447—Fine grey claystone, no shell, some lignite.	
11448—Fine grey claystone, partly iron-stained, no shell, no lignite.	
11449—Bottom of exposure in stream bed: fine grey claystone, no shell, some lignite.	
<b>Locality: MARINE BEDS NEAR DUNBRODY BRIDGE (SITE 13)</b> (page 46)	
Latitude: 33°28'33"S	Longitude: 25°33'44"E
Samples collected (SOEKOR Laboratory number and description)	
11468—Variably cemented lignitic silty sandstone with oysters and gastropods.	
11469—Fine grey claystone with rare lignite, no shell.	
11470—Fine grey claystone with lignite and plant fragments, no shell.	
11471—Silty grey claystone with rare lignite, no shell.	
11472—Fine, slightly silty, grey claystone, with rare lignite, no shell.	
11473—Lignitic grey clayey sandstone with rare oyster shell.	
11474—Lignitic grey clayey sandstone with common oyster shell.	
<b>Locality: PAALTJIESKRAAL (SITE 4)</b> (page 46)	
Latitude: 33°28'59"S	Longitude: 25°30'28"E
Samples collected (SOEKOR Laboratory number and description)	
4905—Fine grey claystone in Kirkwood Formation, doubtful shell, no lignite.	
4906—Fine pinkish-grey claystone in Kirkwood Formation, no shell, no lignite.	
4907—Oyster band, with partly cemented brownish-grey clayey sandstone.	



<b>Locality: ZOUTKLIP (SITE 5)</b> (page 46)	
Latitude: 33°28'22"S	Longitude: 25°30'37"E
Samples collected (SOEKOR Laboratory number and description)	
4908—Fine, silty grey claystone in Kirkwood Formation, with rare lignite, shell.	
4909—Fine, iron-stained brownish-grey claystone in Kirkwood Formation, no lignite, no shell.	
4910—Fine grey carbonaceous claystone with plant remains, Kirkwood Formation, no shell.	
4911—Brownish-grey clayey sandstone with <i>Unio</i> shells in Kirkwood Formation, some lignite.	
<b>Locality: BEZUIDENHOUT RIVER (WEST OF SITE 10)</b> (page 46)	
Latitude: 33°28'35"S	Longitude: 25°31'47"E
Samples collected (SOEKOR Laboratory number and description)	
4912—Fine grey claystone 2 m below oyster bed: bottom. No lignite, no shell.	
4913—Fine silty brownish-grey claystone 1 m below oyster bed. Rare lignite, no shell.	
4914—Oyster bed with iron-stained, brownish silty sandstone.	
4915—Fine silty grey claystone 1 m above oyster bed. No lignite, no shell.	
4916—Sandy greyish siltstone with <i>Unio</i> shells, about 30 m above oyster bed: top. No lignite.	
<b>Locality: BLUE CLIFF STATION (SITE 2)</b> (page 46)	
Latitude: 33°29'45"S	Longitude: 25°28'16"E
Samples collected (SOEKOR Laboratory number and description)	
4917—Fine brownish-grey claystone below sandstone; no lignite, no shell.	
4918—Fine grey claystone, above sandstone, no lignite, no shell.	
<b>Locality: DUNBRODY STATION (SITE 10)</b> (page 46)	
Latitude: 33°28'23"S	Longitude: 25°32'24"E
Samples collected (SOEKOR Laboratory number and description)	
4919—Oyster band above canal: shelly, silty iron-stained sandstone.	
4919.1—Fine pale grey claystone no lignite, no shell.	
4919.2—Fine pale grey claystone no lignite, no shell.	
4919.3A—Clayey and silty partly cemented brownish sandstone with oysters and bivalves, rare lignite.	
4919.3B—Clayey and silty partly cemented brownish sandstone with rare shell and lignite.	
4919.4—Grey, very cemented silty sandstone with lignite, bivalves, oysters and gastropods.	
4919.5A—Grey cemented silty sandstone with oysters and bivalves, rare lignite.	
4919.5B—Sandy grey claystone with rare bivalve shell and some lignite.	
4919.6—Fine silty grey claystone with rare oyster shell and rare lignite.	

**Locality: MFULENI (SITE 15)** (see also McLachlan & McMillan 1976: 206) (page 46)

Latitude: 33°27'51"S

Longitude: 25°31'36"E

## Samples collected (SOEKOR Laboratory number and description)

4816—Top: Sandy pale grey claystone, no shell, rare lignite.

4817—Very sandy pale grey claystone, no shell, rare lignite.

4818—Slightly silty pale grey claystone, no shell some lignite.

4819—Silty grey claystone, no shell or lignite.

4820—Cemented silty sandstone, freshwater ostracods (*Cypridea*), very rare lignite.4821—Friable silty sand, freshwater ostracods (*Cypridea*), very rare lignite.

4822—Fine pale grey claystone, some cementing, no shell, no lignite.

4823—Silty pale grey claystone, no shell some lignite.

4824—Very silty pale grey claystone, no shell, no lignite.

4825—Fine grey claystone, very lignitic no shell.

4826—Silty fine grey claystone, few siderite spheres, no shell, no lignite.

4827—Silty grey claystone, slight iron-staining, no shell or lignite.

4828—Bottom: silty grey claystone, abundant lignite, no shell.

**Locality: CASTLE CLIFF** (page 47)

Latitude: 33°28'39"S

Longitude: 25°35'37"E

## Samples collected (SOEKOR Laboratory number and description)

18588—Claystone in cliff below massive sandstone with gastropods, oysters, bivalves, lignite.

**Locality: LOW LEVEL BRIDGE** (page 47)

Latitude: 33°28'26"S

Longitude: 25°35'53"E

## Samples collected (SOEKOR Laboratory number and description)

18589—Grey claystone with rare shells; weathered sample.

**Locality: THE LOOK OUT (SITE 14)** (page 47)

Latitude: 33°28'26"S

Longitude: 25°36'22"E

## Samples collected (SOEKOR Laboratory number and description)

18590—Laminated siltstone and claystone, no shell: top.

18591—Siltstone with claystone laminae; shells (bivalves (+*Trigonia*) and gastropods) in fine sandstone lenses; some lignite.

18592—Claystone with silty laminae; bivalves; lignite on siltier bedding planes.

18593—Claystone with silty laminae; bivalves (+ *Perna*) and lignite on silty bedding planes.

18594—Silty claystone; no fossils; lignite on bedding planes.

18595—Silty claystone; with *Mytilus*, gastropods and trace lignite.18596—Claystone with 8 cm oyster band; big oysters, *Perna atherstoni* and other bivalves; trace lignite.

18597—Claystone with siltstone laminae; rare shell, trace lignite.

18598—Claystone, trace lignite on bedding planes, no shell.

18599—Claystone, trace lignite on bedding planes; no shell.

<b>Locality: UITENHAGE TO GRAAFF-REINET ROAD CUTTINGS</b> (page 48)	
Latitude: 33°47'10"S	Longitude: 25°25'41"E
Samples collected (SOEKOR Laboratory number and description)	
11463—Basal Sundays River Formation at junction of Port Elizabeth to Uitenhage and Uitenhage to Graaff-Reinet roads: silty grey claystone, no shell or lignite.	
Latitude: 33°46'45"S	Longitude: 25°25'50"E
Samples collected (SOEKOR Laboratory number and description)	
11464—Sundays River Formation 1 km north of junction: very silty glauconitic dark grey claystone, very rare shell, no lignite.	
Latitude: 33°45'47"S	Longitude: 25°25'57"E
Samples collected (SOEKOR Laboratory number and description)	
11465—Sundays River Formation 2.4 km north of junction: top: fine grey claystone, slightly iron-stained, no shell or lignite.	
11466—Sundays River Formation 2.4 km north: bottom, 1.6 m below 11465: fine grey claystone, slightly iron-stained, no shell or lignite.	
<b>Locality: ZOETGENEUGD (NORTH END OF CLIFF)</b> (page 52)	
Latitude: 33°35'37"S	Longitude: 25°38'51"E
Samples collected (SOEKOR Laboratory number and description)	
11974—Top: sandy grey claystone, with secondary gypsum, no shell, very rare lignite.	
11975—Fine grey claystone, no shell, very rare lignite.	
11976—Very sandy grey claystone, no shell very rare lignite.	
11977—Very silty grey claystone, no shell, very rare lignite. ?Secondary gypsum.	
11457—Very silty grey claystone, no shell, some lignite.	
11978—Silty grey claystone, no shell, very rare lignite. Secondary gypsum.	
11979—Fine grey claystone, no shell, some lignite.	
11980—Silty grey claystone, no shell, some lignite.	
11981—Very silty grey claystone, no shell, some lignite.	
11456—Very finely silty grey claystone, no shell, some lignite.	
11982—Very silty grey claystone, no shell some lignite.	
11983—Slightly silty grey claystone, no shell, moderate lignite.	
11454—Very silty grey claystone, very rare shell, moderate lignite.	
11455—Very silty grey claystone, some cemented sandstone, oysters, moderate lignite.	
11450—Very silty grey claystone, no shell rare lignite.	
11451—Very sandy greyish claystone, some cemented sandstone, some shell and lignite.	
11984—Slightly silty grey claystone, rare shell, moderate lignite.	
11452—Very sandy greyish claystone, some cemented sandstone, oysters, rare lignite.	
11453—Bottom: very sandy greyish claystone, some cemented sandstone, oysters, moderate lignite.	
Latitudes and longitudes from 1:50 000 topographic sheets (Gauss Conform Projection Central Meridian 25°East—Clarke 1880 Spheroid). 3325AD (KIRKWOOD) 3325BC (COERNEY) 3325DA (ADDO) 3325CD/3425AD (UITENHAGE) 3325DB (COLCHESTER) 3325DC+DD/3425BA (PORT ELIZABETH)	



## INTERPRETED PALAEOENVIRONMENTS

Although much discussion has been engendered over the years on the age of the Sundays River Formation, comparatively little comment has been made on its environment of deposition. Shone (1976*a*, 1976*b*, 1978) examined the sedimentological and lithological features of Sundays River outcrops and the fully-cored borehole sections AD 1/68 and PA 1/68. He regarded the outcrops and sections studied by him to indicate that the Sundays River Formation accumulated in a tidal-flat environment.

Valicenti & Stephens (1984), from their examination of the ostracods, regarded the later part of the Late Valanginian, where ostracods are abundant, to have accumulated in a warm-water, shallow-marine environment with an abundant food supply. Rare brackish-water and marginal-marine ostracods occur at this time too, indicating a close proximity to fluvial environments. In contrast, in the Early Hauterivian, a different, poor ostracod fauna is preserved, which they considered as indicative of a sudden deepening and cooling of the sea that occurred close to the Valanginian–Hauterivian boundary. In the Late Hauterivian, ostracods once more become abundant, and they reflect a middle-shelf environment of deposition, again with genera typical of brackish and marginal marine facies also present.

Although not immediately evident, these lithological and ostracodal interpretations reflect different aspects of the same depositional model. The variation and range of depositional environments within the Sundays River Formation seem to be greater than understood by either Shone (1976*a*, 1976*b*, 1978) or Valicenti & Stephens (1984). It appears that most of Shone's (1976*a*) conclusions arguing for a tidal-flat environment derive from outcrops and boreholes located near the northern perimeter of the Sundays River Formation (Zoetgeneugd outcrop round to borehole PA 1/68). In contrast, the remarks of Valicenti & Stephens (1984) are based mainly on those areas where ostracods are common, that is, the southern outcrops (such as Coega Brick Pits and Colchester Cliff) and the adjacent borehole sections.

## LATE VALANGINIAN

Figures 21 to 24 show the distribution of the various depositional environments recognized on the basis of the foraminifera faunas for two time-slices in the Late Valanginian and one each in the Early and Late Hauterivian.

The basal Sundays River Formation accumulated in a marginal-marine and estuarine environment. Poor foraminifera faunas occur widely (Biozones C and D) immediately following the transgression over the Kirkwood Formation, suggesting that freshwater influence remained strong throughout the onshore Algoa Basin for some time after the initial marine incursion. Subsequently, depositional environments became more differentiated. Shallow-marine and estuarine environments, strongly affected by freshwater input, prevailed throughout Late Valanginian times in the north and east of the Sundays River Formation. As has been pointed out by Shone (1976*b*: 40), the maximum diversity of macro-invertebrates occurs near to the present-day coast, with least diversity

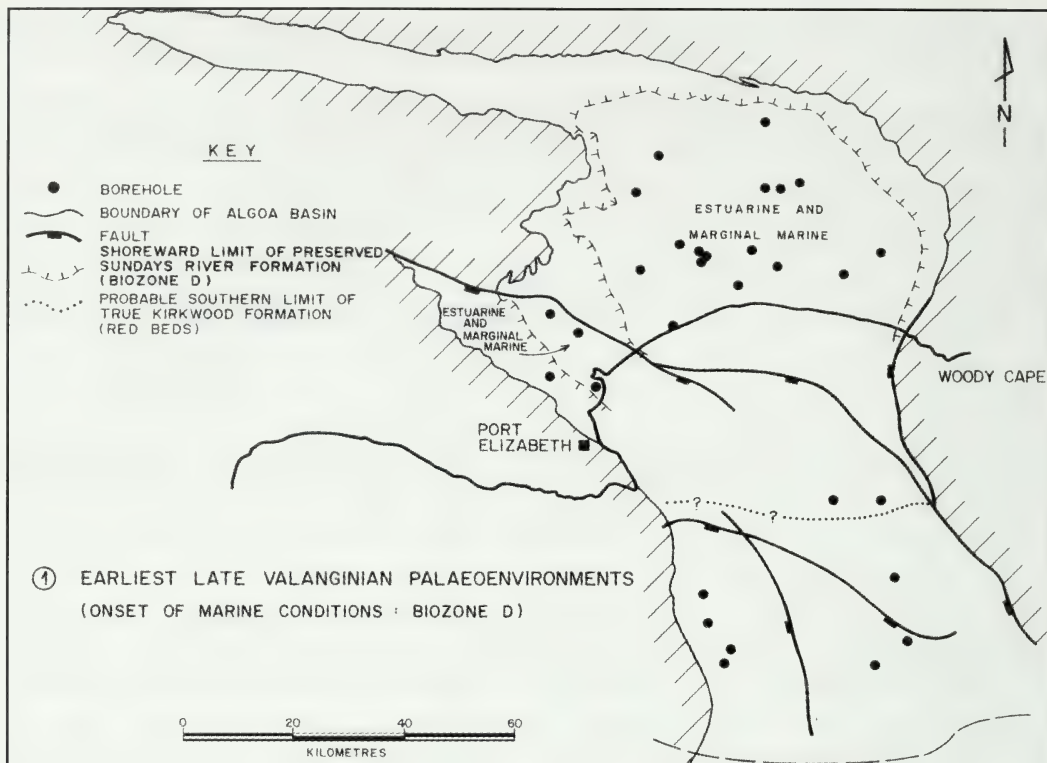


Figure 21.  
Depositional environments of the Sundays River Formation  
in the earliest Late Valanginian (Biozone D).

occurring in the north: foraminifera diversities parallel this distribution. Shone's (1976a, 1976b) arguments for a tidalite style of deposition in the north are convincing, but further south, the diversity of foraminifera and the presence of small numbers of Radiolaria (Fig. 77A–J) suggest an outer-shelf to uppermost-slope environment of deposition. The two cleanest, deepest marine sections studied are MV 1/79 and AL 1/69 boreholes, and they yielded the most diverse foraminifera faunas and the greatest numbers of Radiolaria. However, different drilling techniques, and the resulting rather poor samples from VO 1/71, CO 2/70, CO 3/71, and KE 1/71, make it impossible to determine the areal extent of Radiolaria in the Sundays River Formation.

### EARLY HAUTERIVIAN

As reviewed at the beginning of this section, Valicenti & Stephens (1984) interpreted a substantial water-depth and temperature change over the Valanginian–Hauterivian boundary, based on changes in ostracod faunas. The presence of small numbers of Radiolaria in borehole MV 1/79 in the later Late Valanginian and in the earlier Early Hauterivian, and only a little change in the species of foraminifera present through this interval (though foraminifera abundances are very different), suggest that water depths

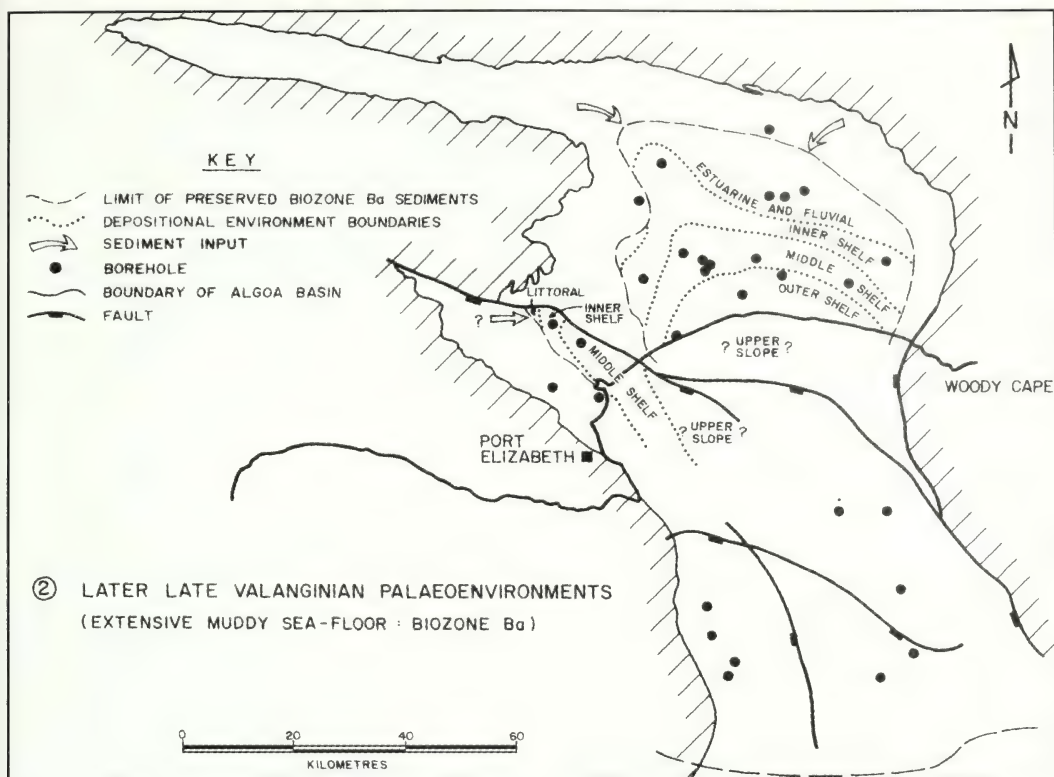


Figure 22.

Depositional environments of the Sundays River Formation  
in the later Late Valanginian (Biozone Ba).

and water chemistry changed little during this period. The same is true of the Valanginian–Hauterivian boundary elsewhere, where it occurs in relatively clean or cored borehole sections (AL 1/69, CO 1/67, SM 1/76). The major decline in foraminifera abundance in the Early Hauterivian (Fig. 10) is believed to have been caused by fluctuating sediment input into the Algoa Basin at this time. The tectonic disturbances that caused the 1At1 unconformity, and a possible Valanginian–Hauterivian boundary unconformity were followed by increased sediment input, so that the sea-floor as far out as the shelf-break was flooded by sand lobes. During these sandy incursions, foraminifera numbers declined on the sea-floor; and post-depositional leaching of calcite within these sands has further reduced the numbers of microfossils recovered.

### LATE HAUTERIVIAN

In the Late Hauterivian, sea-floor conditions began to quieten again: decreased rates of sediment input led to generally finer-grained sedimentation and a corresponding increase in abundance and diversity of foraminifera. Leaching of the clayey sediments has been impeded by their low permeability, and microfossil preservation remains generally good. The marked difference between the foraminifera assemblages of clayey and sandy



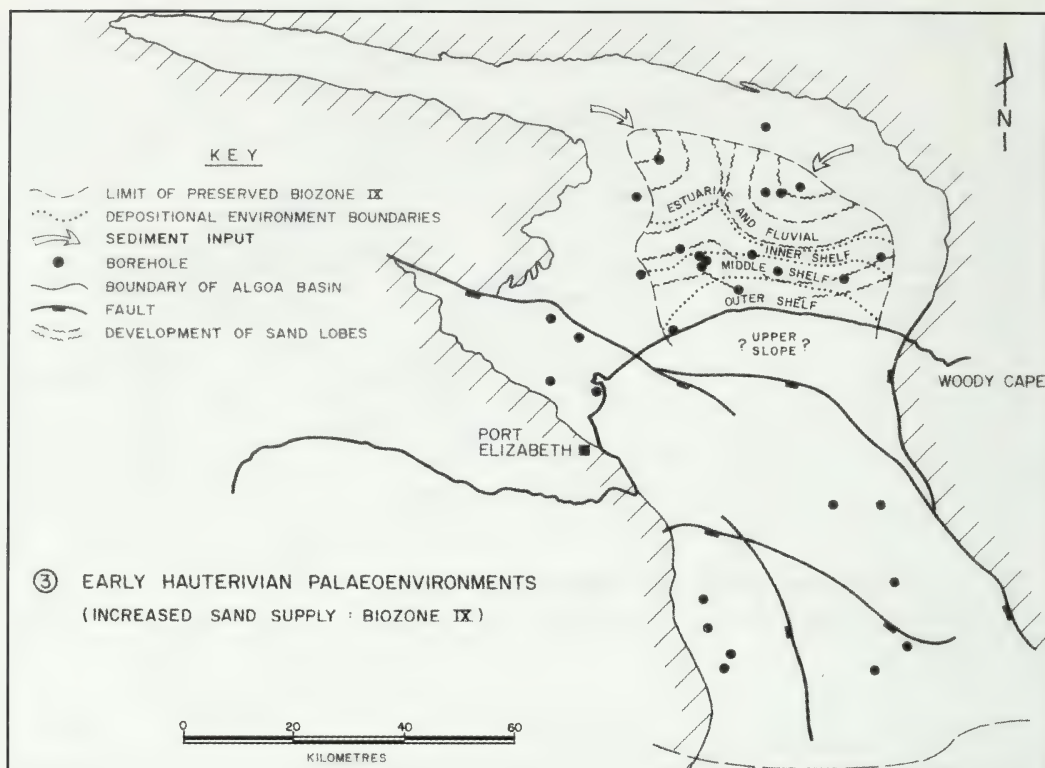


Figure 23.  
Depositional environments of the Sundays River Formation  
in the Early Hauterivian (Biozone IX).

intervals is particularly clear in the cleanly drilled Late Hauterivian section of borehole AL 1/69.

As in the Late Valanginian, the distal Sundays River Formation in the Late Hauterivian would seem to have accumulated in an outer-shelf or uppermost-slope environment. Close to the northern margin of the Formation, marginal marine and estuarine conditions prevailed throughout the Late Valanginian and Hauterivian, most notably in the north-east (NA boreholes). Sand lobes continued to extend southward, but are thinner and less frequent in the Late Hauterivian. They contain abundant *Ammobaculites subaequalis* Mjatluk with occasional attached *Bullopore laevis* (Sollas). Presumably during episodes of increased sediment input, when sand lobes were reaching as far as the distal parts of the onshore Algoa Basin, conditions were too disturbed on the sea-floor to permit argillophilic species to occupy the northern part of the Basin. Post-depositional leaching, preferentially through the more permeable sands may well have destroyed most calcitic foraminifera tests that were in the sands at the time of deposition. *Ammobaculites subaequalis* is certainly the thickest-walled agglutinated foraminifera encountered in the Sundays River Formation, and may have best survived leaching processes. However, the presence of *Bullopore laevis* in some of the sands indicates that not all calcite has been removed.

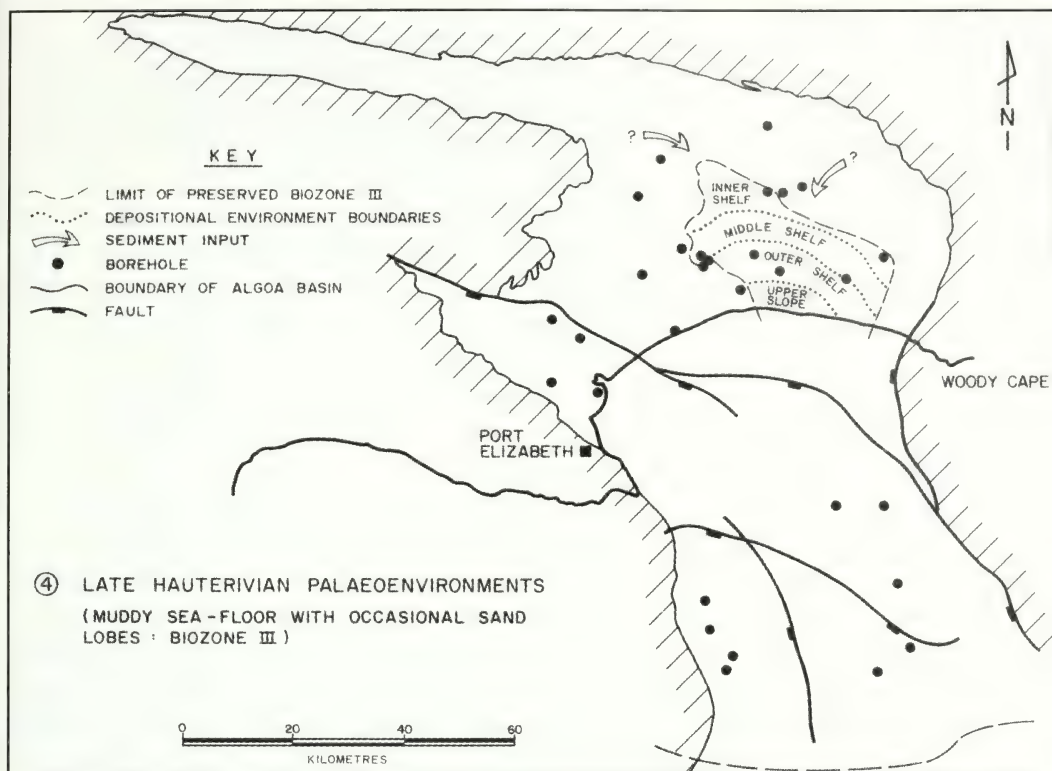


Figure 24.

Depositional environments of the Sundays River Formation in the Late Hauterivian (Biozone III).

## OXYGEN LEVELS AND WATER TEMPERATURES

At the commencement of Sundays River Formation deposition, oxygen levels were high (Biozones D and C), and water depths were probably typical of innermost shelf localities. During the times of Biozones Bb and Ba, water depths show a greater range, from outermost shelf in the south to estuarine and tidal in the north and north-east but, although foraminifera are abundant, species diversity is not very high. Species of *Epistomina*, *Reinholdella*, *Ammobaculites* and *Haplophragmoides* predominate. In contrast, offshore boreholes in the Algoa Basin (especially Hb–D1) do not show this feature, and nodosarids, especially *Lenticulina* species, are much more common in the time-equivalent strata. The same species of *Epistomina*, *Reinholdella*, *Ammobaculites* and *Haplophragmoides* do occur in the offshore boreholes, but in smaller numbers.

The predominance of aragonitic species in the Sundays River Formation onshore suggests that environments during Bb and Ba times were distinctly restricted, with lowered oxygen levels at the sea-floor. The presence of Radiolaria at this time, as in MV 1/79, indicates that oxygen conditions in the surface waters were probably near normal. The offshore basement high associated with the Coega–St Croix fault system (see Fig. 2) acted as a sill to the Sundays River Trough to the north until 1At1 (latest

Valanginian) times, and as a consequence, sea-floor oxygen values seem to have been somewhat reduced, and foraminifera faunas rather restricted. Unfortunately, the few, rather shallow marine sections of this interval examined in the Uitenhage Trough (ST 1/71 and SW 2/68), and thus south of the basement high do not reveal a substantially different assemblage. The reason for this is not clear.

It seems probable that in the silled Sundays River Trough, water temperatures were somewhat higher than in the adjoining regions. Valicenti & Stephens (1984) and Valicenti (pers. comm., 4 November 1986) have remarked on the frequency with which *Cytherelloidea* occurs in Late Valanginian near-shore environments of the Cape south coast. This ostracod genus is restricted to warm waters at the present day. However, that the northern Algoa Basin could not have been too warm is indicated by the complete lack of any type of larger foraminifera throughout the sequence; none are known either from other contemporaneous deposits in southern Africa.

As mentioned previously, above 1At1 (top Biozone Ba) the Sundays River Formation is much more sandy than below, and microfaunas are much poorer. From the thin-walled, unornamented ostracods that occur here (latest Valanginian and Early Hauterivian), Valicenti & Stephens (1984) have considered that water depths increased, and water temperatures declined abruptly. In contrast, the foraminifera show little change, except in numbers of specimens being significantly less. This perhaps is indicative of little change in either water temperatures or water depths, but rather reflects a marked increase in sediment input into the Sundays River Trough from the time of the Biozone Ba–Biozone A boundary to the top of the Early Hauterivian. In the Late Hauterivian, sandstones become less abundant again, and there is a consequent increase in diversity and abundance of foraminifera faunas. The reduced oxygen levels of the Sundays River Trough were eliminated as the offshore Coega–St Croix high subsided during the Hauterivian, and thereafter became blanketed with sea-floor sediment.

Palaeolatitude reconstructions for the Valanginian–Hauterivian period by Smith & Briden (1977) indicate that the south coast of South Africa then lay at about 53°S. In fault-controlled depocentres of the Pletmos, Gamtoos and Algoa basins, sedimentation rates for the Valanginian and Hauterivian are high, attaining 400 to 600 m (uncorrected) per million years locally. Sediment supply and freshwater runoff from the land were clearly considerable at this time. Foraminifera faunas of the Sundays River Formation are considered to reflect cool, temperate marine conditions, although, as mentioned above, the Sundays River Trough may have been a little warmer (though not tropical) during the Late Valanginian Biozones Ba and Bb.

#### PALAEOECOLOGY OF FORAMINIFERA GROUPS OF THE SUNDAYS RIVER FORMATION

The onshore Algoa Basin during Sundays River Formation times was dominated by substantial freshwater and sediment input that together define the types of foraminifera found. A summary of the following data is shown in Figure 25. Agglutinated foraminifera form a substantial proportion of studied assemblages. Species of the genera



*Ammobaculites* and *Haplophragmoides* predominate in shallow marine, innermost shelf environments where oxygen values range from near normal to greatly lowered, and salinities are usually somewhat reduced. Large numbers of these two genera also occur at inner- to outer-shelf locations, in association with calcareous foraminifera. In more restricted, rather reduced oxygen conditions on the shelf, *Ammoglobigerina*, *Trochammina* and *Dorothia* occur in some numbers, as in the Hauterivian of CK 1/68.

Environments affected by markedly hyposaline water, as during the basal Sundays River transgression, are characterized by a predominance of *Miliammina* specimens. Locally, hyposaline environments may be referable to a particular estuary, but the precise situation during the basal transgression, with the widespread occurrence of 'estuarine' conditions at that time remains rather unclear.

Nodosarid genera such as *Lenticulina*, *Astacolus*, *Citharina*, *Planularia*, *Pravoslavlevia* and others are found most abundantly on the shelf, but, with the exception of *Citharina*, appear to avoid the innermost shelf and marginal marine conditions. Polymorphinids, in contrast, seem to be most frequent in stressful environments. In the Colchester Member of the Uitenhage Trough, *Eoguttulina* and *Globulina* are believed to be associated with broad mudflats at the mouth of an estuary (McMillan 1980), but in the Sundays River Formation they occupy a wider array of stressful environments. The two genera also do occur in substantial numbers in marginal marine, probably reduced salinity facies of the Sundays River Formation, but on the middle and outer continental shelf, large numbers may be associated with short-lived periods of low sea-floor oxygen levels. Attached forms such as *Bullopore* are most numerous in the thin sands of the Late Hauterivian, where they are almost always found on large tests of *Ammobaculites* on the middle and outer shelf, perhaps suggesting turbulent sea-floor conditions at these times.

Attached miliolids (*Nubecularia*, *Vinelloidea*, and ?*Calcitornella*) occur in two distinct environments: close to shore, in or near the littoral (*Vinelloidea*, as at the Uitenhage to Graaff-Reinet Road outcrop) and further out on the continental shelf (*Nubecularia* and ?*Calcitornella*), where, with *Bullopore*, they occur most notably in the Late Hauterivian, though they are not especially associated with the thin sands. Attached miliolids at the present day often occur in environments with a high dissolved oxygen level, particularly in protected littoral and sublittoral environments along wave-swept rocky shores. It may be that their presence in the more offshore Late Hauterivian reflects higher oxygen values at that time. Free miliolids (*Cornuspira* and *Quinqueloculina*) are surprisingly scarce, occurring occasionally across the shelf. The free-living representatives of the genus *Nodobacularia* are confined to nearshore localities.

The concentration of miliolids seen on the South African inner shelf at the present day is not echoed in the Sundays River Formation, probably because of the generally hyposaline proximal environments in the Algoa Basin. However, one species of *Quinqueloculina* does occur extensively and in great numbers through the marginal marine, mostly mudflat environments of the Colchester Member of the Uitenhage Trough (McMillan 1980).

The aragonitic genera *Epistomina*, *Reinholdella* and *Conorboides* occur in variable numbers from the inner to outer shelf, but only *Epistomina* appears to venture close to

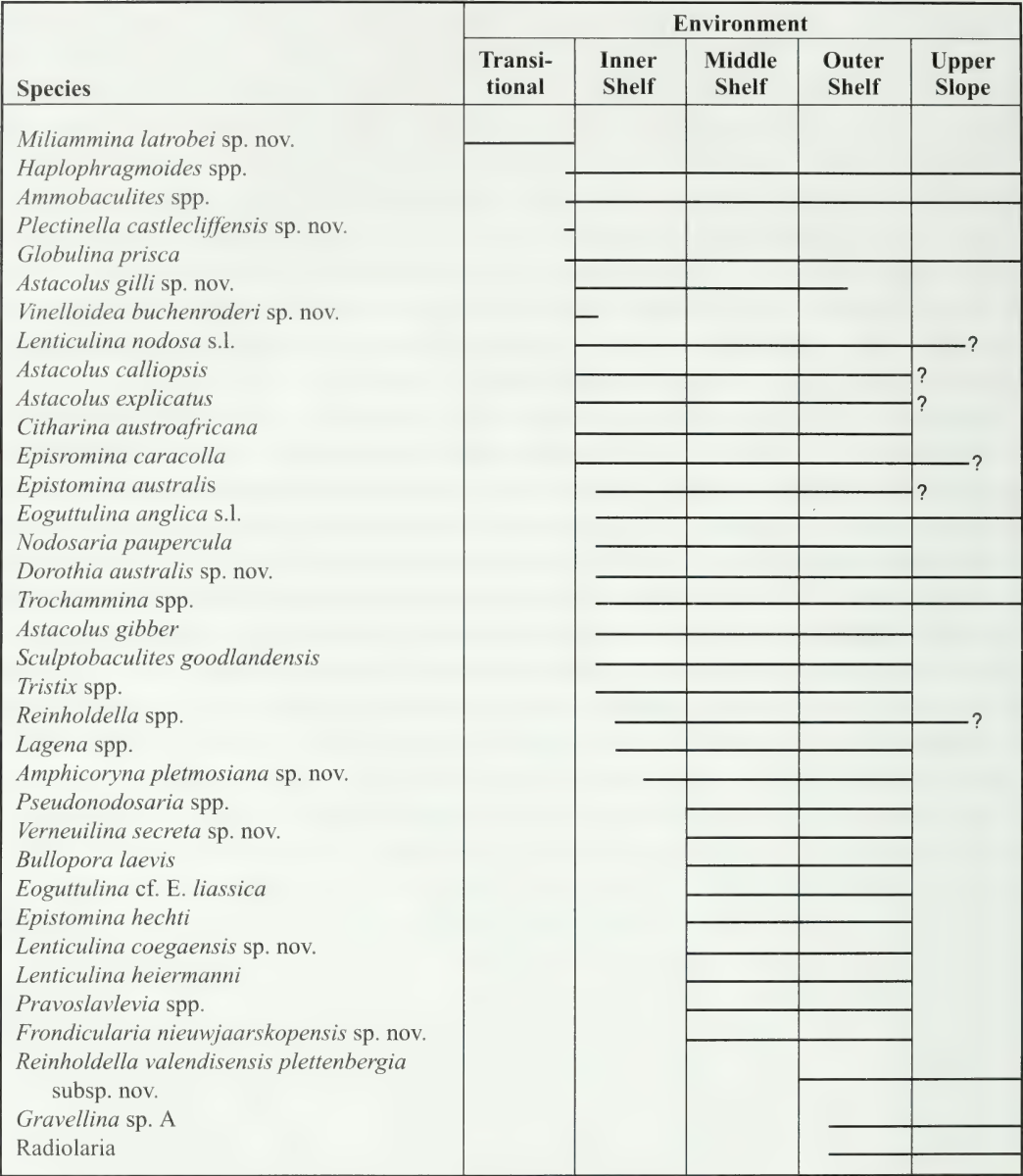


Figure 25

Interpreted depth ranges of selected foraminifera species from the Sundays River Formation.

shore, and all three genera avoid hyposaline (?and hypersaline) conditions near the margins of the basin. Floods of *Epistomina*, dominating foraminifera assemblages, appear to be typical of organic-rich shelf claystones (often with hemipelagic qualities and characterized by high gamma electric log responses) at a number of horizons in the South African Late Jurassic (Portlandian) and Early Cretaceous (Early Berriasian and later Early Barremian).

## SELECTIVE PRESERVATION

Weathering of microfaunas from outcrops is clearly seen at a number of localities, and leaching of microfaunas may occur in sandy intervals of boreholes. Study of many surface outcrop samples has provided an indication of the progressive elimination of the foraminifera faunas. Percolating groundwater containing oxygen and humic and inorganic acids penetrates Sundays River strata. Macrofossil and microfossil shell debris begins to be leached and precipitated elsewhere as calcite cement, vein calcite, or over other macrofossil and microfossil material. Leached microfossils appear as corroded remnants: thick test walls and features such as umbilical bosses and infillings, limbate sutures, peripheral keels and prolocular areas tend to survive, whereas the thinner chamber walls are removed. *Lenticulina* and *Epistomina* tests, for example, thus tend to show a 'skeletal' effect. In such cases, the chamber infillings, exposed to percolating water, begin to deteriorate. Calcite infillings appear to suffer at much the same rate as the foraminifera shell, but pyrite fillings, which are usually composed of microframboidal spheres, weather rapidly to rust colour iron oxides and carbonates. Such weakened tests are easily destroyed during insensitive sample processing. Pyritized Radiolaria and true framboids that have been oxidized in this way also suffer during processing. Where leached calcite re-precipitates on calcareous microfossils, crystal overgrowths occur on calcite foraminifera shells, often developing to such an extent that precise identification of specimens is impossible.

Further leaching selectively removes all calcareous tests, leaving exclusively agglutinated assemblages. Of course, it may prove to be very difficult to establish whether an agglutinated assemblage is a residue of a larger one formerly containing calcitic species, or one that has always been 100 per cent agglutinated. Only analysis of suites of samples from vertical sections, with comparisons of intensity of leaching, and of relative abundances and preservation of calcareous tests, as well as comparisons between outcrop and borehole data for the same interval, can establish the intensity of test corrosion at outcrops. As with pyrite infillings of leached calcareous shells, pyrite-infilled agglutinated tests show a rust-red coloration through the damaged test wall when corroded. More intense leaching would seem to selectively remove those agglutinated tests with a calcite cement, leaving the exclusively siliceous forms as the most resistant remnant of Sundays River Formation faunas.

## TAXONOMY

The foraminifera of the Sundays River Formation are dominated by several groups, particularly nodosarids, epistominids and agglutinated species. Miliolids are usually rare, and rotalids of all types, except the aragonitic genera, are absent. The majority of the species encountered range through most or all of the Sundays River Formation, but there are a number that are confined to specific intervals, and these have been of considerable use in establishing the foraminifera biozonation. Summarized stratigraphic ranges of the foraminifera detailed in the taxonomic section are shown in Figure 26 (*fold out chart at the back of this Volume*). A taxonomic index is given in Table 4.



TABLE 4

List of species and other material described, together with page and figure references.

Species	Page	Figures
<i>Saccamina</i> spp.	74	27A–B
<b><i>Pelosina zoetgeneugdensis</i></b> sp. nov.	74	27C–F
<i>Ammodiscus</i> spp.	75	27G–H
<i>Hormosina</i> sp. A	75	27I
<i>Reophax</i> spp.	77	27J, 28A–B
<i>Haplophragmoides</i> sp. A	79	28C–E
<i>Haplophragmoides</i> sp. B	81	28F–H
<i>Haplophragmoides</i> sp. C	81	28I–J, 29A
<i>Haplophragmoides</i> sp. D	82	29B–E
<i>Haplophragmoides</i> sp. F	82	29F–I
<i>Haplophragmoides</i> spp.	83	—
<i>Ammobaculites subaequalis</i> Mjatluk	83	30A–D
<i>Ammobaculites</i> sp. A	86	30E
<i>Ammobaculites</i> sp. B	86	30F–I
<i>Ammobaculites</i> sp. C	87	30J–K
<i>Ammobaculites parvispira</i> Ten Dam	87	31C–G
<i>Ammobaculites</i> spp.	89	—
<i>Sculptobaculites goodlandensis</i> (Cushman & Alexander)	89	31A–B
<i>Placopsilina cenomana</i> d'Orbigny	90	32
<b><i>Textularia zoetgeneugdia</i></b> sp. nov.	91	31H–K
<i>Ammoglobigerina</i> cf. <i>A. globigeriniformis</i> (Parker & Jones)	93	31L–M
<i>Trochammina</i> cf. <i>T. inflata</i> (Montagu)	94	33A–D
<b><i>Trochammina sundaysriverensis</i></b> sp. nov.	95	33E–H, 34A–C
<i>Trochammina</i> spp.	98	—
<b><i>Verneuilina secreta</i></b> sp. nov.	98	33I, 35A–D
<i>Verneuilina</i> sp. B	99	35E
<b><i>Gaudryinella alexandria</i></b> sp. nov.	101	35F–I
<i>Dorothia</i> sp. A	103	35J, 36A–D
<b><i>Dorothia inglesidensis</i></b> sp. nov.	103	36E–H, 37A–D
<b><i>Dorothia australis</i></b> sp. nov.	107	36I–L, 38A–B
<i>Gravellina</i> sp. A	109	38C–D
<b><i>Plectinella castlecliffensis</i></b> sp. nov.	111	39A–F
<i>Cornuspira orbicula</i> (Terquem & Berthelin)	113	38E–F
? <i>Calcitornella</i> sp.	113	38G
<i>Nubecularia lucifuga</i> Defrance	115	38H–K, 40A–B
<b><i>Vinelloidea buchenroderi</i></b> sp. nov.	116	40C–F
<i>Nodobacularia</i> sp. A	118	40G
<i>Quinqueloculina</i> spp.	118	40H

Species	Page	Figures
<i>Quinqueloculina minima</i> Tappan	118	42A
<b><i>Miliammina latrobei</i></b> sp. nov.	119	41A–F
<i>Nodosaria paupercula</i> Reuss	121	42B–K
<i>Nodosaria obscura</i> Reuss	124	42L–N, 43A–B
<i>Nodosaria tomaszowiensis</i> Szejn	124	43C–F
<b><i>Nodosaria grisbrooki</i></b> sp. nov.	125	43G–J
<i>Nodosaria</i> cf. <i>N. obscura</i> Reuss	128	43M–N
<i>Pseudonodosaria tenuis</i> (Bornemann)	128	43K–L
<i>Pseudonodosaria humilis</i> (Roemer)	129	60H–K
<b><i>Amphicoryna pletmosiana</i></b> sp. nov.	130	43O–P, 44A–C
<b><i>Astacolus gilli</i></b> sp. nov.	133	44D–G
<i>Astacolus humilis</i> (Reuss)	135	44H–I
<i>Astacolus</i> sp. C	136	44J
<i>Astacolus microdictyotos</i> Espitalié & Sigal <i>s.l.</i>	136	45A–K
<i>Astacolus gibber</i> Espitalié & Sigal	140	46A–H
<i>Astacolus schloenbachi</i> (Reuss)	141	46I–M
<i>Astacolus calliopsis</i> (Reuss) <i>s.l.</i>	144	47A–J
<i>Astacolus explicatus</i> Espitalié & Sigal <i>s.l.</i>	145	48A–K
<i>Astacolus</i> sp. A	147	47K
<i>Astacolus</i> sp. D	148	47M
<i>Astacolus</i> spp.	149	47N
<i>Citharina</i> sp. A	149	48L
<i>Citharina pseudostriatula</i> Bartenstein & Brand	149	48M–N, 49A–B
<b><i>Citharina austroafricana</i></b> sp. nov.	153	49C–J
<i>Dentalina communis</i> d'Orbigny <i>s.l.</i>	156	49K–M
<i>Dentalina linearis</i> (Roemer)	157	50A–C
<i>Dentalina</i> sp. B	157	49N
<i>Dentalina</i> spp.	157	49O–P
<b><i>Fronicularia nieuwaarskopensis</i></b> sp. nov.	157	50D–G
<b><i>Lagena alexandria</i></b> sp. nov.	161	50H–L
<i>Lagena</i> sp. A	162	51A
? <i>Lagena</i> sp.	163	51B
<b><i>Lagena algoensis</i></b> sp. nov.	163	51C–J
<i>Lagena haueriviana haueriviana</i> Bartenstein & Brand	166	52A–B
<i>Lagena haueriviana cylindracea</i> Bartenstein & Brand	167	52C
<i>Lagena</i> spp.	169	52D
<b><i>Lenticulina coegaensis</i></b> sp. nov.	169	52E–G
<i>Lenticulina</i> sp. A	171	47L, 52H
<i>Lenticulina</i> cf. <i>L. saxonica</i> Bartenstein & Brand	172	52J–K
<i>Lenticulina nodosa</i> (Reuss) <i>s.l.</i>	172	53A–I, 54A–F
<i>Lenticulina heiermanni</i> Bettenstaedt	177	54G–J

Species	Page	Figures
<i>Lenticulina subtilis</i> (Wisniowski)	179	55A–B
<i>Lenticulina muensteri</i> (Roemer) <i>s.l.</i>	180	55C–F
<i>Lenticulina</i> cf. <i>L. cultrata</i> (Montfort)	180	55G–H
<i>Lenticulina</i> spp.	181	—
<i>Marginulina</i> sp. A	181	55I
? <i>Marginulina pyramidalis</i> (Koch)	181	56A
<i>Marginulinopsis parkeri</i> (Reuss)	181	56B
<i>Neoflabellina</i> cf. <i>N. malakialinensis</i> Espitalié & Sigal	183	56C–E
<i>Palmula</i> sp.	184	56F
<i>Planularia madagascariensis</i> Espitalié & Sigal <i>s.l.</i>	184	56G–L, 57A–D
<b><i>Planularia formosa</i></b> sp. nov.	187	57E–M
<i>Planularia</i> sp. A	189	58A
<i>Planularia</i> sp. B	191	58B–C
<i>Planularia</i> sp. C	191	57N
<i>Planularia</i> spp.	192	58D
<i>Pravoslavlevia frankei</i> (Ten Dam)	192	58E–J
<i>Pravoslavlevia pravoslavlevi</i> (Fursenko & Polenova)	193	58K–L, 59A–C
<i>Psilocitharella arguta</i> (Reuss)	195	59D–G
<i>Vaginulina</i> spp.	196	59H–M
<i>Vaginulinopsis</i> sp. A	197	59N
<i>Vaginulinopsis</i> cf. <i>V. matutina</i> (d'Orbigny)	197	60A–C
<i>Vaginulinopsis</i> cf. <i>V. prima</i> (d'Orbigny)	199	60D–G
<i>Lingulonodosaria nodosaria</i> (Reuss)	200	60L–N
<i>Paralingulina hexacarinata</i> (Espitalié & Sigal)	201	60O–P, 61A
<b><i>Lingulina trilobita</i></b> sp. nov.	202	61B–F
<i>Lingulina bettenstaedti</i> (Zedler)	205	61G–H, N
<i>Lingulina praelonga</i> Ten Dam	206	61I–K
<i>Lingulina simplicissima</i> (Ten Dam)	206	61L–M
<b><i>Lingulina mngazanaensis</i></b> sp. nov.	207	62B–I
<i>Lingulina</i> sp. A	210	62K
<i>Lingulina</i> cf. <i>L. furcillata</i> Berthelin	210	62L–M
<i>Lingulina</i> spp.	211	62A, J
<i>Eoguttulina anglica</i> Cushman & Ozawa <i>s.l.</i>	211	62N–O, 64A–B
<i>Eoguttulina</i> cf. <i>E. inovroclaviensis</i> (Bielecka & Pożaryski)	212	63A–C
<i>Eoguttulina</i> cf. <i>E. liassica</i> (Strickland)	213	64C–E
<i>Eoguttulina</i> cf. <i>E. polygona</i> (Terquem)	215	64F–G
<i>Eoguttulina</i> sp. B	215	64H–I
<i>Globulina prisca</i> Reuss <i>s.l.</i>	216	64J–N
<b><i>Pseudopolymorphina colchesterensis</i></b> sp. nov.	216	65A–H
<i>Pyrulina cylindroides</i> (Roemer)	219	66C–D
<i>Webbinella subhemisphaerica</i> Franke	220	65I–J



Species	Page	Figures
<i>Bullopora laevis</i> (Sollas)	221	65K–L, 66A–B
<i>Ramulina fusiformis</i> Khan	223	66E
<i>Ramulina</i> spp.	224	66F–G
<i>Tristix acutangula</i> (Reuss)	224	66H–K, 67A
<i>Tristix excavata</i> (Reuss)	225	67B–E
<i>Spirillina tenuissima</i> Gümbel	228	67F–G
<i>Conorboides</i> sp. A	228	67H, 68A
<i>Epistomina hechti</i> Bartenstein, Bettenstaedt & Bolli	229	68B–H
<i>Epistomina australis</i> Masiuk & Viña	231	68I, 69A
<i>Epistomina caracolla</i> (Roemer) <i>s.l.</i>	233	69E–I, 70A–I, 72A–E
<i>Reinholdella valendisensis</i> (Bartenstein & Brand)	239	72F–I, 73A–F
<i>Reinholdella</i> sp. D	245	73G–I
<b><i>Reinholdella platterugensis</i></b> sp. nov.	246	74A–H
<i>Reinholdella valendisensis</i> <b><i>plettenbergia</i></b> subsp. nov.	248	74I
<i>Reinholdella</i> sp. C	249	76A
<i>Reinholdella hofkeri</i> (Bartenstein & Brand)	249	76B–G
? <i>Colomia</i> sp.	252	76H–I
Radiolaria	252	77A–J
Bivalves	253	78A
Mysid statoliths	253	78B, D
Arthropods: 'shrimps'	255	79A–D
Echinoid spines	255	78C
Crinoid ossicles	255	78E–G
Echinoderm debris	257	78H
Ophiuroid ossicles	257	80B
Holothurian sclerites	257	78I, 80A
Hexiseds	259	80C
?Charophyte oogonia	259	80D

The suprageneric taxonomic classification used is that of Loeblich & Tappan (1964, 1974), amended by Haynes (1981). Generic revisions indicated by Loeblich & Tappan (1986, 1988) are included. The classification is given from family level only; the above references provide additional details.

All illustrated and described specimens, including holotypes, paratypes and comparative material, have been deposited in the collections of the South African Museum, Cape Town. Each individual specimen has been allocated a catalogue number, prefixed SAM–PQ–MF, and numbered from 1133 to 1643 inclusive. For convenience, reference to the catalogued material in the text is abbreviated by omitting the prefix SAM–PQ. The original 2 022 assemblage slides remain in the microfossil slide collections in SOEKOR (Pty) Ltd.\*, in Parow, Cape Town. In the text and captions, references to negative numbers (e.g. F2930) refer to the SOEKOR photographic archive\*, and in the captions the biozones are placed in parentheses.

\*Now held by PASA (Petroleum Agency of South Africa) in Parow.

## Order FORAMINIFERIDA Eichwald, 1830

Family **Saccamminidae** Brady, 1884

Subfamily Saccammininae Brady, 1884

Genus *Saccammina* Carpenter, 1869*Saccammina* spp.

Figs 27A–B

*Remarks*

Small, subspherical tests with coarsely agglutinated walls are widely distributed through the Sundays River Formation. Never common, none are especially distinctive, and none show any particular stratigraphic range. These specimens may be related to the *Proteonina difflugiformis* (Brady) illustrated by Bartenstein & Brand (1951, pl. 1 (fig. 3)) from the Late Valanginian of north-west Germany.

Genus *Pelosina* Brady, 1879***Pelosina zoetgeneugdensis*** sp. nov.

Figs 27C–F

*Diagnosis*

A *Pelosina* species with an elongate, spindle-shaped test.

*Etymology*

From its occurrence in the Zoetgeneugd Cliff outcrop.

*Material*

*Holotype* (Fig. 27C). MF1135, SOEKOR negative F250.

*Paratypes* (Fig. 27D–F). MF1136 to MF1138, 3 specimens, SOEKOR negatives F512, F300, and F256.

*Stratum Typicum*

The Zoetgeneugd Cliff outcrop, within highest Biozone C (Late Valanginian) of the Sundays River Formation.

*Locus Typicus*

Zoetgeneugd Cliff sample 11452.

*Description*

Test elongate, spindle-shaped, circular in cross-section, and composed of a single chamber. Tests usually taper more rapidly to one end than the other, so that maximum test width is rarely at mid-height. Test wall composed of variably sized, often coarse-grained quartz particles, rather irregularly arranged, resulting in a roughened test surface. The ratio of quartz grains to cement is high. Irregular, subcircular, unornamented openings exist at both ends of the test.

*Remarks*

*Pelosina zoetogeneugdensis* is distinct from other species of the genus in its elongate, sub-cylindrical test, and in this respect, differs markedly from other Early Cretaceous forms. *Pelosina lagenoides* Crespin, 1953, from the Early Cretaceous of the Great Artesian Basin of Australia is a much more subglobular form with a relatively smooth test wall of fine-grained particles. The test wall of *P. zoetogeneugdensis* is rather more coarse-grained than is usual for the genus.

*Stratigraphic range in the Sundays River Formation*

Occurs in very small numbers at the top of Biozone C (Late Valanginian) at Zoetogeneugd Cliff outcrop, and in the Hauterivian Biozones III and VII in the more distal boreholes.

Family **Ammodiscidae** Reuss, 1862

Subfamily Ammodiscinae Reuss, 1862

Genus *Ammodiscus* Reuss, 1862

*Ammodiscus* spp.

Figs 27G–H

*Remarks*

Poorly preserved tests of *Ammodiscus* occur rarely in the Sundays River Formation. Several appear similar to *Ammodiscus gaultinus* Berthelin, particularly to the illustrations given by Bartenstein & Brand (1951, pl. 1 (fig. 13)). However, Magniez-Jannin (1975: 26) has regarded many of the forms previously referred to *A. gaultinus* as more properly assigned to *Glomospirella*; amongst these she includes the Valanginian specimens of Bartenstein & Brand (1951). The present material is too poor to permit analysis of the variation present in the Sundays River Formation tests.

*Stratigraphic range in the Sundays River Formation*

Occasional tests occur throughout, from Biozone Bb up to Biozone I, generally at more distal localities.

Family **Lituolidae** de Blainville, 1825

Subfamily Hormosininae Haeckel, 1894

Genus *Hormosina* Brady, 1879

*Hormosina* sp. A

Fig. 27I

*Remarks*

Five specimens, all broken, of a multilocular, uniserial form. The last-formed chamber possesses a long apertural neck, as illustrated, and in this respect, the species shows some similarity to *Reophax deckeri* Tappan (1940: 94, pl. 14 (figs 3a–b)), also subsequently illustrated by Crespin (1963: 23, pl. 3 (figs 1–10)). There is also slight similarity to some tests of *R. scorpiurus* Montfort, as figured by Magniez-Jannin (1975: 27, pl. 1 (figs 9–18)).



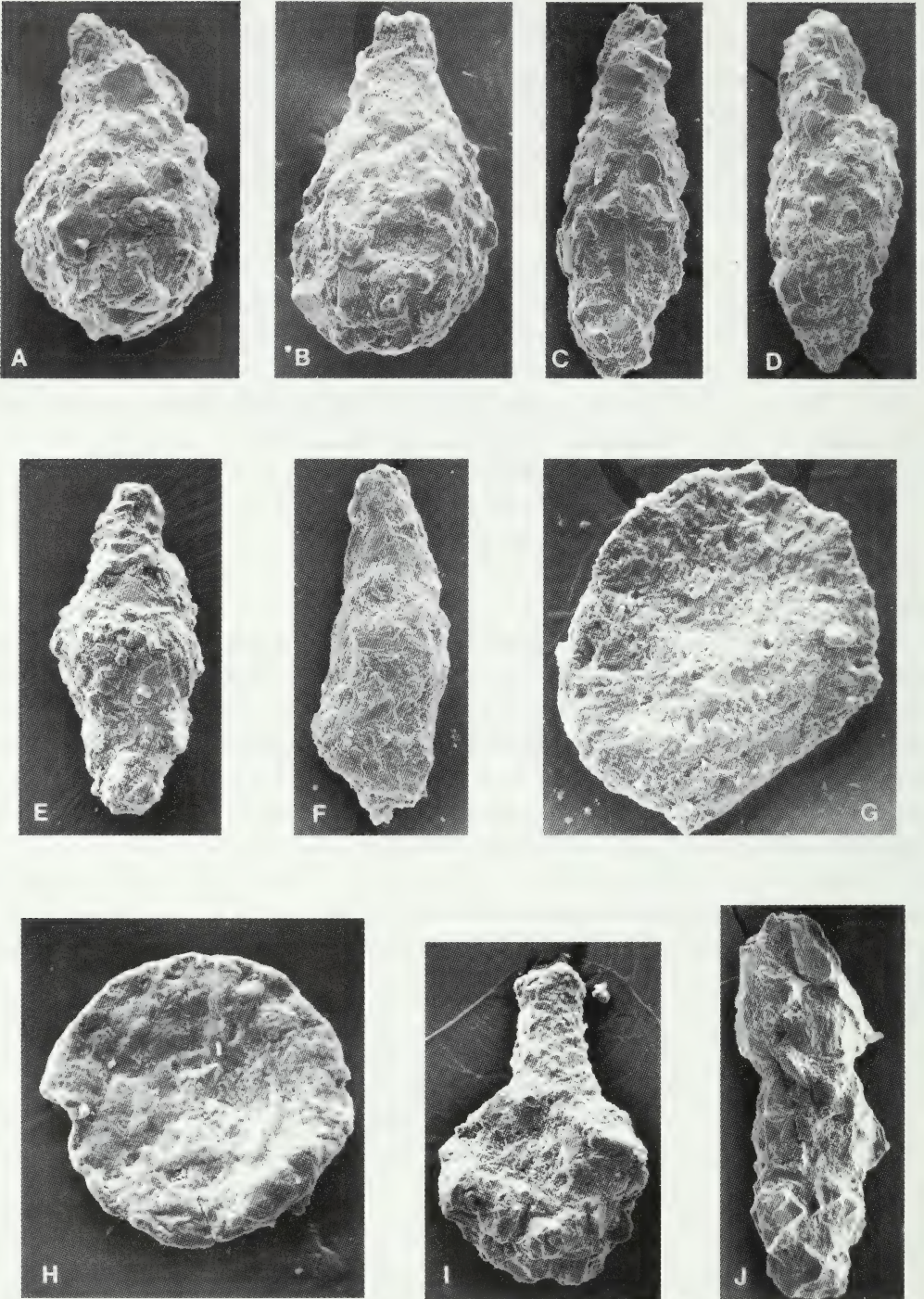


Figure 27.

Comparable tests to those of the Sundays River Formation also occur in the South African Late Aptian and Albian.

*Stratigraphic range in the Sundays River Formation*

All tests are from the Late Hauterivian Biozones VII to I.

Genus *Reophax* Montfort, 1808

*Reophax* spp.

Figs 27J, 28A–B

*Reophax* sp. Beer, 1970: 70, pl. 1 (fig. 1). Stapleton & Beer, 1977: 2, pl. 3 (fig. 8).

*Remarks*

Generally poorly preserved specimens of *Reophax* are found sporadically through the Sundays River Formation. Some degree of variation can be seen in the grain size in the test wall, and in the inflation of the chambers, sufficient to suggest that a number of species are represented. None of these specimens possess the nearly globular chambers and constricted sutural necks of *Hormosina* sp. A. A dearth of well-preserved *Reophax* tests in the material precludes any attempt to identify this material to species at present.

*Stratigraphic range in the Sundays River Formation*

Late Valanginian (Biozone Ba) to Late Hauterivian (Biozone II). This rare genus is restricted to shelf environments where normal marine conditions prevailed, and is never found associated with high- or reduced-oxygen sea-floor conditions, nor with the reduced salinity marginal facies that prevailed along the northern margin of Sundays River Formation deposition.

Subfamily Haplophragmoidinae Maync, 1952

Genus *Haplophragmoides* Cushman, 1910

*Remarks*

Analysis of the abundant *Haplophragmoides* specimens from the Sundays River Formation is greatly hampered by the variable degree of test distortion due to post-

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Fig. 27 (see facing page). A–B. *Saccammina* spp. A. SAM–PQ–MF1133, side view, AL 1/69, 1 000 feet (III), F293.  $\times$  133. B. SAM–PQ–MF1134, side view, AL 1/69, 460 feet (I), F106.  $\times$  67. C–F. *Pelosina zoetogeneugdensis* sp. nov. C. Holotype, SAM–PQ–MF1135, side view, Zoetogeneugd Cliff outcrop sample 11452 (C), F250.  $\times$  106. D. Paratype, SAM–PQ–MF1136, side view, AL 1/69, 2 410 feet (VIII), F512.  $\times$  70. E. Paratype, SAM–PQ–MF1137, side view, AL 1/69, 1 000 feet (III), F300.  $\times$  107. F. Paratype, SAM–PQ–MF1138, side view, Zoetogeneugd Cliff outcrop sample 11452 (C), F256.  $\times$  93. G–H. *Ammodiscus* spp. G. SAM–PQ–MF1139, side view, Zoetogeneugd Cliff outcrop sample 11450 (Bb), F244.  $\times$  164. H. SAM–PQ–MF1140, side view, AL 1/69, 460 feet (I), F112.  $\times$  138. I. *Hormosina* sp. A, SAM–PQ–MF1141, side view, AL 1/69, 1 480 feet (IV), F386.  $\times$  76. J. *Reophax* sp., SAM–PQ–MF1142, side view, MV 1/79, 380–390 m (Ba), F646.  $\times$  68.



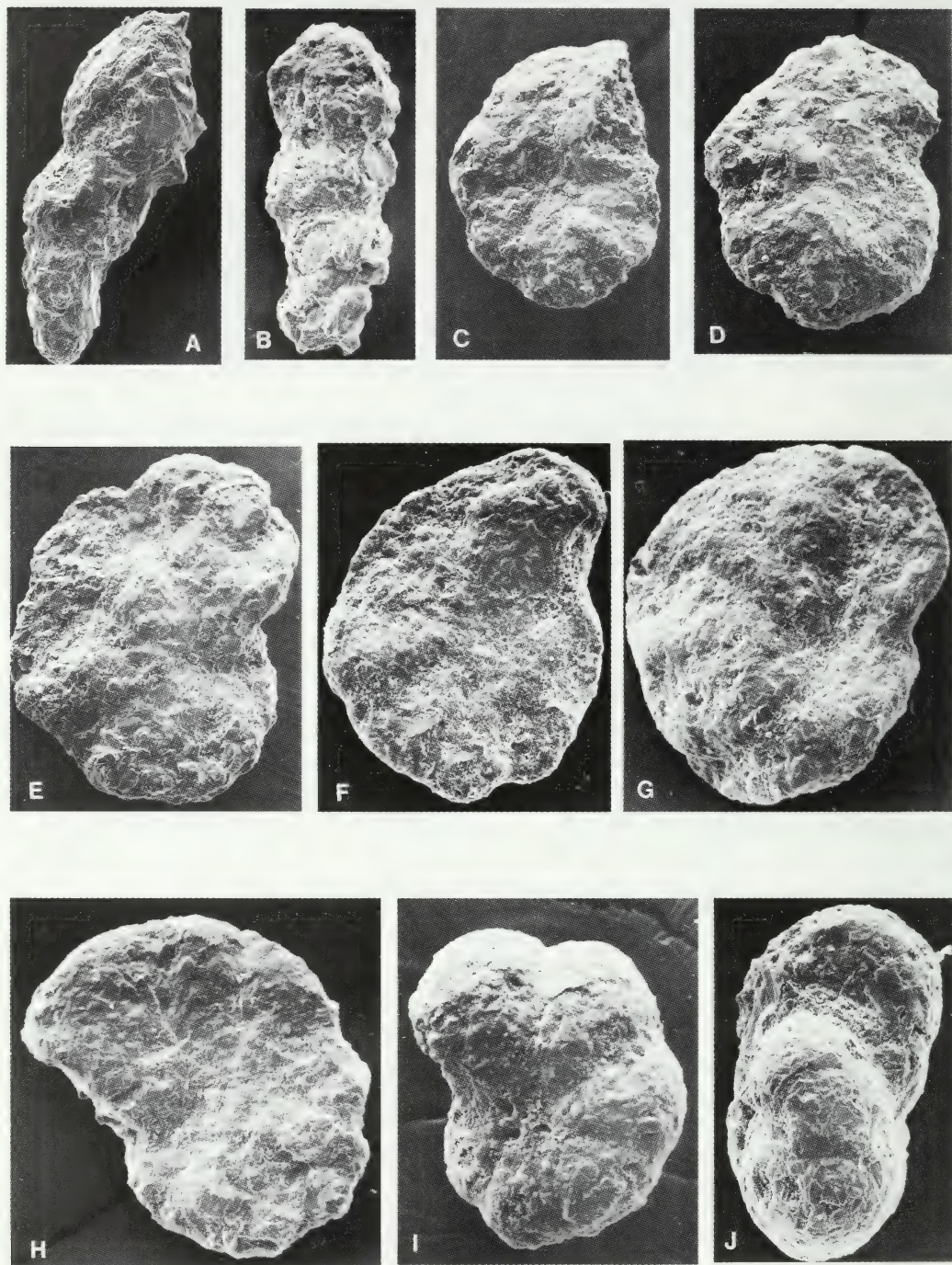


Figure 28.



depositional compaction within the sediment. Distinctly different morphologies can be seen that are due solely to how tests have been aligned and compacted within the sediment. Differences also occur if calcite or pyrite infilling of the chamber cavities has occurred early or late in the diagenetic sequence. It has thus often proved difficult to distinguish between species effectively within this genus, as many of the diagnostic details of tests have been obliterated. Post-depositional compaction has particularly affected the degree of chamber inflation and degree of lobation of the test periphery, the depth of the umbilicus, and whether sutures are depressed or flush, straight or curved. However, distinctive features such as the number of chambers in the final whorl, the nature of the grains and cement composing the test wall, and even the intensity of compaction (reflecting the thickness of the test wall) can be sufficient to compose a basic subdivision of the group. Nevertheless, because of the relative paucity of data determined for these *Haplophragmoides* morphotypes, it seems unwise to consider them as formal species. For this reason, they are listed informally below, and little or no attempt has been made to compare them with previously described *Haplophragmoides* species. Because of their mode of preservation, the aperture of virtually all *Haplophragmoides* tests from the Sundays River Formation is not visible, although it is presumed to be interio-marginal at the base of the terminal face of the final chamber; no other details are discernible. A comparison with the species of *Haplophragmoides* described by Masiuk & Viña (1987) from the Early Hauterivian of Chubut, Argentina, gives an indication of the difficulties that arise in attempting to use this group of foraminifera as a correlation tool.

*Haplophragmoides* sp. A

Figs 28C–E

*Remarks*

This morphotype is characterized by a strongly compressed test with weakly inflated chambers, usually six in the final whorl, generally with a slightly depressed umbilicus on both sides of the test, and with a moderate grain size of angular quartz particles and moderate quantities of cement comprising the test wall. The test periphery is distinctly lobate and circular in outline, rounded to sub-rounded in cross-section, although these features are often severely affected by post-depositional compaction. Sutures appear to be straight and radiate, weakly depressed.

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Fig. 28 (see facing page). A–B. *Reophax* spp. A. SAM–PQ–MF1143, side view, shallow borehole SB–31, core 1, 91 feet 6 inches (IV), F691.  $\times 55$ . B. SAM–PQ–MF1144, side view, AL 1/69, 580 feet (II), F174.  $\times 126$ . C–E. *Haplophragmoides* sp. A. C. SAM–PQ–MF1145, side view, AL 1/69, 340 feet (I), F37.  $\times 91$ . D. SAM–PQ–MF1146, side view, AL 1/69, 340 feet (I), F36.  $\times 85$ . E. SAM–PQ–MF1147, side view, AL 1/69, 310 feet (I), F33.  $\times 69$ . F–H. *Haplophragmoides* sp. B. F. SAM–PQ–MF1148, side view, AL 1/69, 1 360 feet (IV), F371.  $\times 106$ . G. SAM–PQ–MF1149, side view, AL 1/69, 3 510 feet (X), F539.  $\times 96$ . H. SAM–PQ–MF1150, side view, AL 1/69, 3 840 feet (X), F543.  $\times 85$ . I–J. *Haplophragmoides* sp. C. I. SAM–PQ–MF1151, side view, AL 1/69, 340 feet (I), F35.  $\times 178$ . J. SAM–PQ–MF1152, apertural view, AL 1/69, 1 150 feet (IV), F340.  $\times 95$ .

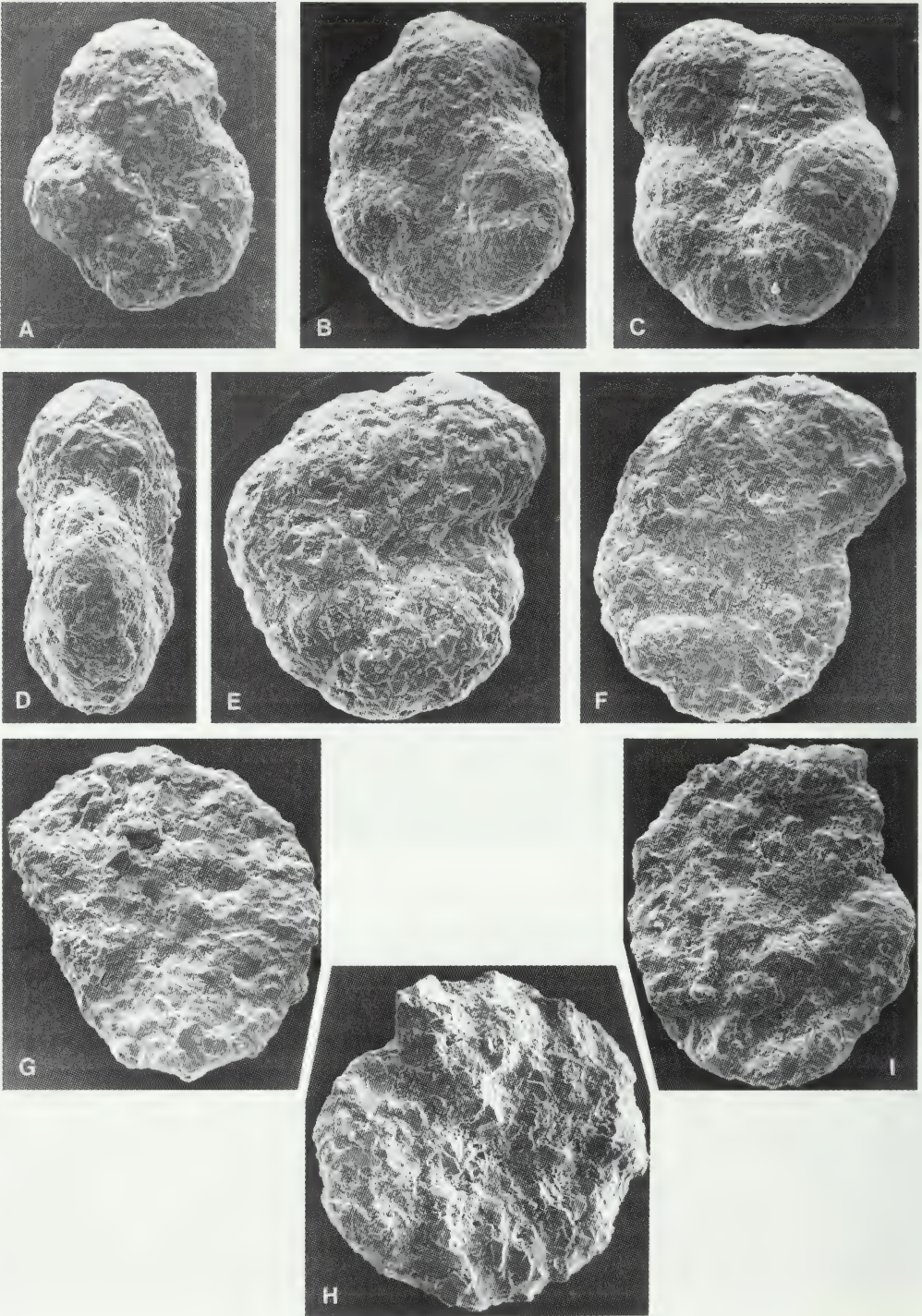


Figure 29.



Tests of *Haplophragmoides* sp. A occur in considerable numbers throughout most of the Sundays River Formation. It is possible that they are conspecific with *Haplophragmoides* sp. B described from the Late Valanginian and Early Hauterivian (Biozones B to IX) of borehole PB-A1, and the earliest Late Valanginian (Biozone D) of the Brenton Formation (McLachlan *et al.* 1976b).

#### *Stratigraphic range in the Sundays River Formation*

*Haplophragmoides* sp. A ranges consistently from Late Valanginian Biozone C to Late Hauterivian Biozone I. It appears to be absent in reduced-salinity, marginal-marine environments.

#### *Haplophragmoides* sp. B Figs 28F–H

#### *Remarks*

Tests of this morphotype are always severely compressed, so that the generalized description given below little reflects the true test morphology. Eight or nine chambers in the final whorl, weakly but variably inflated. Faintly depressed umbilicus; rather irregularly lobate test periphery, originally rounded in cross-section but diagenetically altered to sub-angular in most specimens; sutures slightly depressed, radiate, either curved or straight. Test wall composed of medium-sized angular quartz particles with moderate quantities of cement.

#### *Stratigraphic range in the Sundays River Formation*

This morphotype occurs frequently through most of the Sundays River sequence, from Late Valanginian Biozone Bb to Late Hauterivian Biozone I. Its environmental preferences are not as clear-cut as those of *Haplophragmoides* sp. A.

#### *Haplophragmoides* sp. C Figs 28I–J, 29A

#### *Remarks*

Chambers planispirally, occasionally rather streptospirally (see Fig. 28J) arranged, inflated and subglobular in form. Umbilicus depressed; sutures depressed, radiate,

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Fig. 29 (see facing page). A. *Haplophragmoides* sp. C, SAM-PQ-MF1153, side view, AL 1/69, 340 feet (I), F34.  $\times 197$ . B–E. *Haplophragmoides* sp. D. B. SAM-PQ-MF1154, side view, AL 1/69, 3 040 feet (IX), F528.  $\times 80$ . C. SAM-PQ-MF1155, side view, AL 1/69, 1 240 feet (IV), F360.  $\times 82$ . D. SAM-PQ-MF1156, apertural view, AL 1/69, 790 feet (III), F227.  $\times 120$ . E. SAM-PQ-MF1157, side view, AL 1/69, 790 feet (III), F226.  $\times 131$ . F–I. *Haplophragmoides* sp. F. F. SAM-PQ-MF1158, side view, AL 1/69, 4 500 feet (Ba), F562.  $\times 100$ . G. SAM-PQ-MF1159, side view, MV 1/79, 80 m (X), F570.  $\times 67$ . H. SAM-PQ-MF1160, side view, MV 1/79, 80 m (X), F571.  $\times 71$ . I. SAM-PQ-MF1161, side view, AL 1/69, 3 840 feet (X), F544.  $\times 73$ .



straight to weakly curved. Five or six chambers in the final whorl. Test periphery distinctly lobate throughout, very broadly rounded in cross-section. Test subglobular in overall shape. Test wall composed of moderately sized, often rather platy quartz grains with moderate cement. This morphotype differs from *Haplophragmoides* sp. D in possessing fewer chambers in the final whorl and in its more nearly globular test.

*Stratigraphic range in the Sundays River Formation*

Restricted to Late Valanginian Biozones Ba and A, and to Late Hauterivian Biozones VII to I. This morphotype is most frequent in distal, more normal marine environments.

*Haplophragmoides* sp. D

Figs 29B–E

*Remarks*

Test rather more compressed than those of *Haplophragmoides* sp. C, with seven inflated chambers in the final whorl. Test periphery lobate, circular in outline and broadly rounded in cross-section. The umbilicus is slightly depressed on both sides of the test. Sutures weakly depressed, straight or faintly curved, radiate. Test wall composed of moderate to fine-grained quartz material, with moderate to rather high quantities of cement.

*Stratigraphic range in the Sundays River Formation*

Early to Late Hauterivian (Biozone X to top Biozone III). Typical of distal, outer-shelf environments with relatively normal sea-floor conditions.

*Haplophragmoides* sp. F

Figs 29F–I

*Remarks*

The test is always strongly compressed due to diagenesis, with a roughly circular outline. Seven or eight chambers in the final whorl, indistinct, except when test is moistened. Sutures flush to very slightly depressed, indistinct, straight, radiate. Test wall composed of moderate, occasionally coarse-grained, angular quartz particles with moderate quantities of cement. These tests, as with those of *Haplophragmoides* sp. B, are so severely compressed that they probably little reflect the form of the original test of the living species.

*Stratigraphic range in the Sundays River Formation*

Restricted to the Late Valanginian and Early Hauterivian (Biozones Ba to X) in deeper marine environments.

*Haplophragmoides* spp.*Remarks*

The majority of *Haplophragmoides* tests from the Sundays River Formation are either badly deformed by post-depositional compaction, or are damaged, so that identification is not possible. These indeterminate specimens of *Haplophragmoides* spp. range from Biozone D to Biozone I, in almost all environments seen in the Sundays River Formation, except the truly estuarine facies of the northern-most Algoa Basin.

Subfamily Lituolinae de Blainville, 1825

Genus *Ammobaculites* Cushman, 1910

*Remarks*

Similar comments to those given for *Haplophragmoides* are valid also for *Ammobaculites*, especially in the case of the smaller, thin-walled species. Again, wall texture, as well as chamber arrangements in the coiled and uncoiled parts of the test remain useful features, even if little can be discovered of the degrees of inflation of chambers, depression of sutures, and the nature of the test periphery. Compare the morphotypes described here with those *Ammobaculites* species detailed by Masiuk & Viña (1987) from the Early Hauterivian of Chubut, Argentina.

*Ammobaculites subaequalis* Mjatluk, 1939

Figs 30A–D

*Ammobaculites subaequalis* Mjatluk, 1939: 44, pl. 2 (fig. 19a–b). Lloyd, 1959: 311, pl. 54 (figs 16–17). Iovcheva, 1962: 48, pl. 1 (fig. 18).

*Haplophragmium subaequale* (Mjatluk). Bartenstein & Brand, 1951: 273, pl. 3 (figs 62a–c, 63a–b, 64a–b). Hanzlíková, 1965: 60, pl. 1 (figs 3–4, 6).

*Haplophragmium aequale* (non Roemer) Beer, 1970: 8.

*Ammobaculites* aff. *A. abnormalis* Crespin. Rigassi, 1970: pl. 83 (2 figs).

*Haplophragmium coprolithiforme subaequale* (Mjatluk). Bielecka, 1975: 308, pl. 1 (figs 9–10), pl. 2 (figs 1–2).

*Remarks*

Sundays River Formation tests are allocated with some hesitation to *Ammobaculites subaequalis*. Almost all northern Algoa Basin examples possess compressed tests that are usually ovate in cross-section, whereas European descriptions indicate *Ammobaculites subaequalis* to be roughly circular in cross-section. The difference may be due to post-depositional compaction of the Algoa tests. In the appressed nature of the chambers, the arrangement of the initial coil, and the simple aperture, the European and South African tests compare closely. The references given above provide an indication of the range of authors' interpretations of the species from the latest Jurassic and Early Cretaceous of Europe.



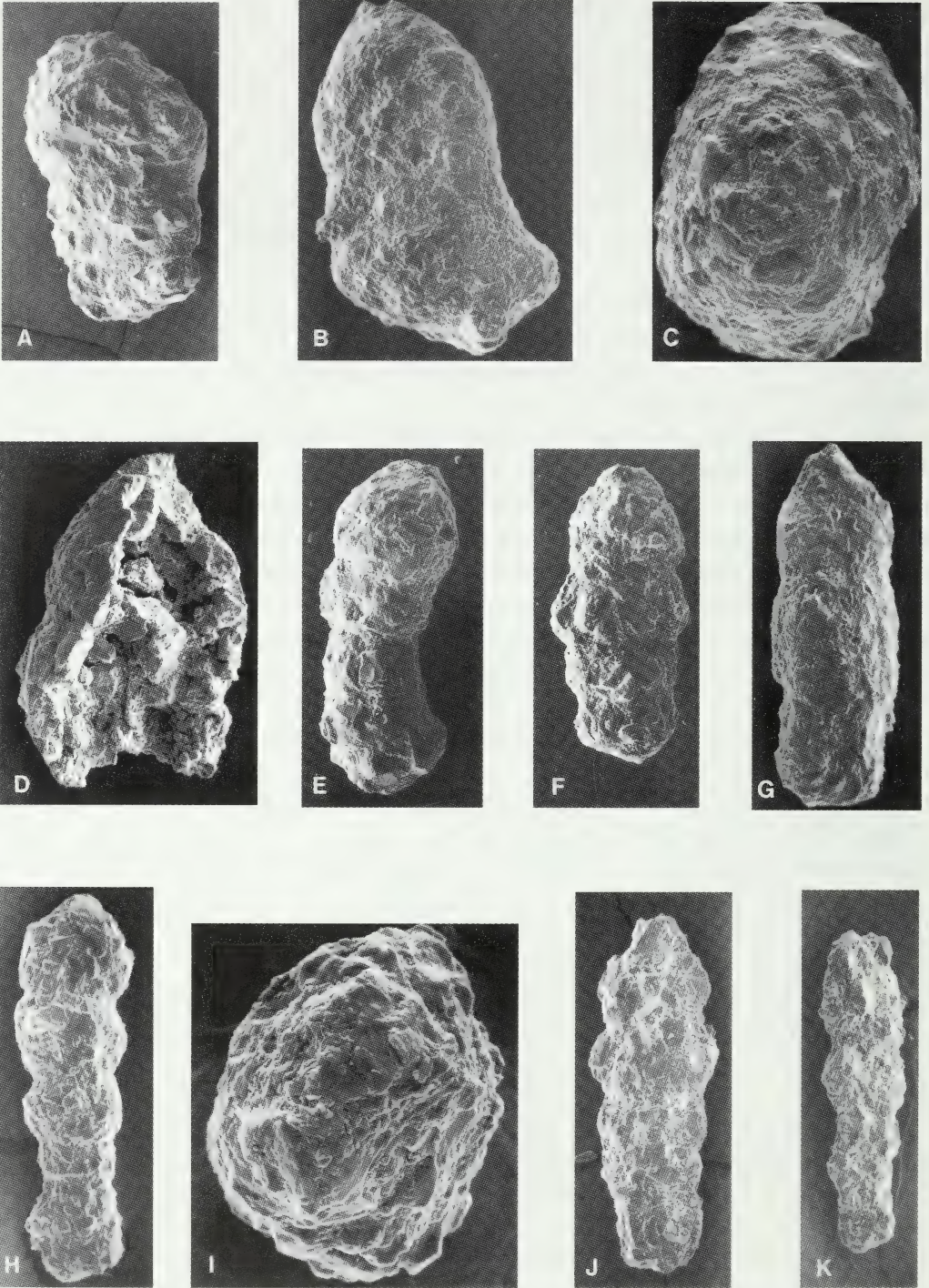


Figure 30.



There appears to be confusion in the literature between the two genera *Ammobaculites* and *Haplophragmium*, particularly regarding the morphologically similar *Ammobaculites subaequalis* and *Haplophragmium aequale* (Roemer). The latter species was described as possessing a multiple, cribrate aperture with a labyrinthic internal chamber wall (Ten Dam 1946). In contrast, Loeblich & Tappan (1964: C244) regarded the interior as simple, the aperture a single opening, and the initial coil streptospiral, whereas the initial coil of *Ammobaculites* is planispiral.

Examination of Sundays River Formation tests failed to reveal any with a cribrate aperture. The interior of the chambers in broken specimens (Fig. 30D) can be considered as 'pseudolabyrinthic', but clearly is not truly labyrinthic. The chamber wall is composed of small and large quartz grains, the latter being aligned so that on the exterior of the test wall they are flush, but on the interior they protrude substantially into the chamber cavity, and result in a very roughened and ragged surface to the internal chamber wall. None of the South African tests display a clearly streptospiral initial coil, although irregularities in positioning of individual chambers do occur.

### Occurrence

Mjatliuk (1939) described *Ammobaculites subaequalis* from the Early Volgian (Portlandian equivalent) of the Volga Basin, Russia. Later records include Late Oxfordian to Kimmeridgian Klentnice Beds of the Czech Republic (Hanzlíková 1965); Kimmeridgian of southern England (Lloyd 1959); Early Kimmeridgian and Middle Portlandian of Poland (Bielecka 1975); Aptian of Bulgaria (Iovcheva 1962); and Middle Bajocian to Early Hauterivian of north-west Germany (Bartenstein & Brand 1951). The species occurs extensively in the South African Late Jurassic and Early Cretaceous, with a total range of Portlandian (Colchester Member of the Uitenhage Trough—McMillan 1980) to Early Aptian. The species appears strongly facies controlled, and is often associated with oxygenated, sandy and turbulent substrates that were probably rather stressful environments for foraminifera.

### Stratigraphic range in the Sundays River Formation

Small but consistent numbers occur through most of the sequence (Late Valanginian

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Fig. 30 (see facing page). A–D. *Ammobaculites subaequalis* Mjatliuk. A. SAM–PQ–MF1162, side view, Uitenhage to Graaff-Reinet Road outcrop sample 11464 (Bb), F87.  $\times 17$ . B. SAM–PQ–MF1163, side view, AL 1/69, 1 570 feet (VI), F423.  $\times 53$ . C. SAM–PQ–MF1164, apertural view, AL 1/69, 3 290 feet (IX), F532.  $\times 63$ . D. SAM–PQ–MF1165, final two chambers broken in half, showing interior, shallow borehole SB–15, core 3, 212 feet (II), F680.  $\times 41$ . E. *Ammobaculites* sp. A, SAM–PQ–MF1166, side view, AL 1/69, 340 feet (I), F38.  $\times 224$ . F–I. *Ammobaculites* sp. B. F. SAM–PQ–MF1167, side view, AL 1/69, 340 feet (I), F39.  $\times 82$ . G. SAM–PQ–MF1168, side view, AL 1/69, 3 070 feet (IX), F529.  $\times 78$ . H. SAM–PQ–MF1169, side view, AL 1/69, 3 450 feet (IX), F537.  $\times 121$ . I. SAM–PQ–MF1170, apertural view, AL 1/69, 1 060 feet (III), F322.  $\times 344$ . J–K. *Ammobaculites* sp. C. J. SAM–PQ–MF1171, side view, AL 1/69, 1 270 feet (IV), F367.  $\times 59$ . K. SAM–PQ–MF1172, side view, Uitenhage to Graaff-Reinet Road outcrop, sample 11464 (Bb), F85.  $\times 68$ .

Biozone C to Late Hauterivian Biozone I). However, the species is especially abundant and generally predominant in sandstone intervals in the Late Hauterivian, often in association with attached *Bullopora* and less frequently with attached *Nubecularia* species. *Ammobaculites subaequalis* is absent in reduced-salinity environments.

*Ammobaculites* sp. A

Fig. 30E

*Remarks*

Tests of *Ammobaculites* with two to three visible chambers in the initial coil, followed by up to five rectilinear chambers that are inflated and subglobular. Sutures distinct, depressed, horizontal in uncoiled part of test. The test wall is composed of very large quartz grains with moderate cement. Tests are circular in cross-section. Aperture a subcircular opening at the terminal point of the final chamber, typical of the genus.

This species is usually little affected by post-depositional compaction, probably because the test wall is so coarsely grained. However, only occasional tests are perfectly preserved, and the example illustrated is a rarity.

*Stratigraphic range in the Sundays River Formation*

Ranges through much of the Sundays River Formation (Biozone Bb to I, Late Valanginian to Late Hauterivian), but is commonest and most persistent in the Late Hauterivian (Biozones VI to I).

*Ammobaculites* sp. B

Figs 30F–I

*Remarks*

Tests are similar in morphology to those of *Ammobaculites* sp. A, but they differ in a number of salient points. The initial coil consists of three visible chambers, and is followed by up to six rectilinear, uncoiled chambers. The chambers are more appressed and not nearly as globular as those of *Ammobaculites* sp. A. Chambers weakly inflated; sutures vary from faint and flush to distinct and depressed, horizontal. Aperture terminal, an irregular subcircular opening (Fig. 30I), which is usually not entirely visible on tests. Test wall composed of fine-grained quartz particles with occasional larger grains and moderate cement. Cross-section of the adult part of the test is circular to subcircular.

*Stratigraphic range in the Sundays River Formation*

Moderate to abundant through much of the sequence, from Late Valanginian Biozone Bb to Late Hauterivian Biozone I. *Ammobaculites* sp. B is less common through most sections of the Early Hauterivian.

*Ammobaculites* sp. C

Figs 30J–K

*Remarks*

Severely compressed tests, with a test wall of fine to moderate-sized quartz grains set in moderate amounts of cement. Two or three chambers visible in the initial coil, with up to four inflated chambers in the rectilinear portion. Sutures depressed, horizontal, straight in uncoiled portion, and indistinct in initial coil. The aperture is always obscured, but presumably terminal and simple in form. These tests have been much affected by post-depositional compaction.

*Stratigraphic range in the Sundays River Formation*

Scattered occurrences from the Late Valanginian (Biozone Bb) to the Late Hauterivian (Biozone IV). The species may occur locally in abundance, especially in the Early Hauterivian.

*Ammobaculites parvispira* Ten Dam, 1950

Figs 31C–G

*Haplophragmium aequale* (non Roemer) Chapman, 1892a: 323, pl. 6 (figs 1–3).

*Ammobaculites parvispira* Ten Dam, 1950: 10, pl. 1 (fig. 8a–b). Neagu, 1965: 4, pl. 1 (figs 1–3).

Magniez-Jannin, 1975: 40, pl. 1 (figs 19–26).

*Remarks*

Many specimens of *Ammobaculites* from the Sundays River Formation are referable to this conservative species. Some variation is evident in South African tests in the shape of the chambers, which may be more or less globular and correspondingly less or more appressed, and in the size of the initial coil, the latter being larger in some specimens than is typical. Gradation can be seen from *Ammobaculites parvispira* towards *Ammobaculites* sp. B.

*Occurrence*

Described from the Albian of the Netherlands (Ten Dam 1950). Other records are from the Albian Gault Clay of Folkestone, England (Chapman 1892a), and the Albian (Magniez-Jannin 1975) and the Early Aptian (Damotte & Magniez-Jannin 1973) of the Aube district, France; farther east the species occurs in the Albian of the Romanian Plain (Neagu 1965).

*Stratigraphic range in the Sundays River Formation*

Occurs throughout the Sundays River Formation (Biozones C to I), and appears to range from marginal-marine to outer-shelf environments.



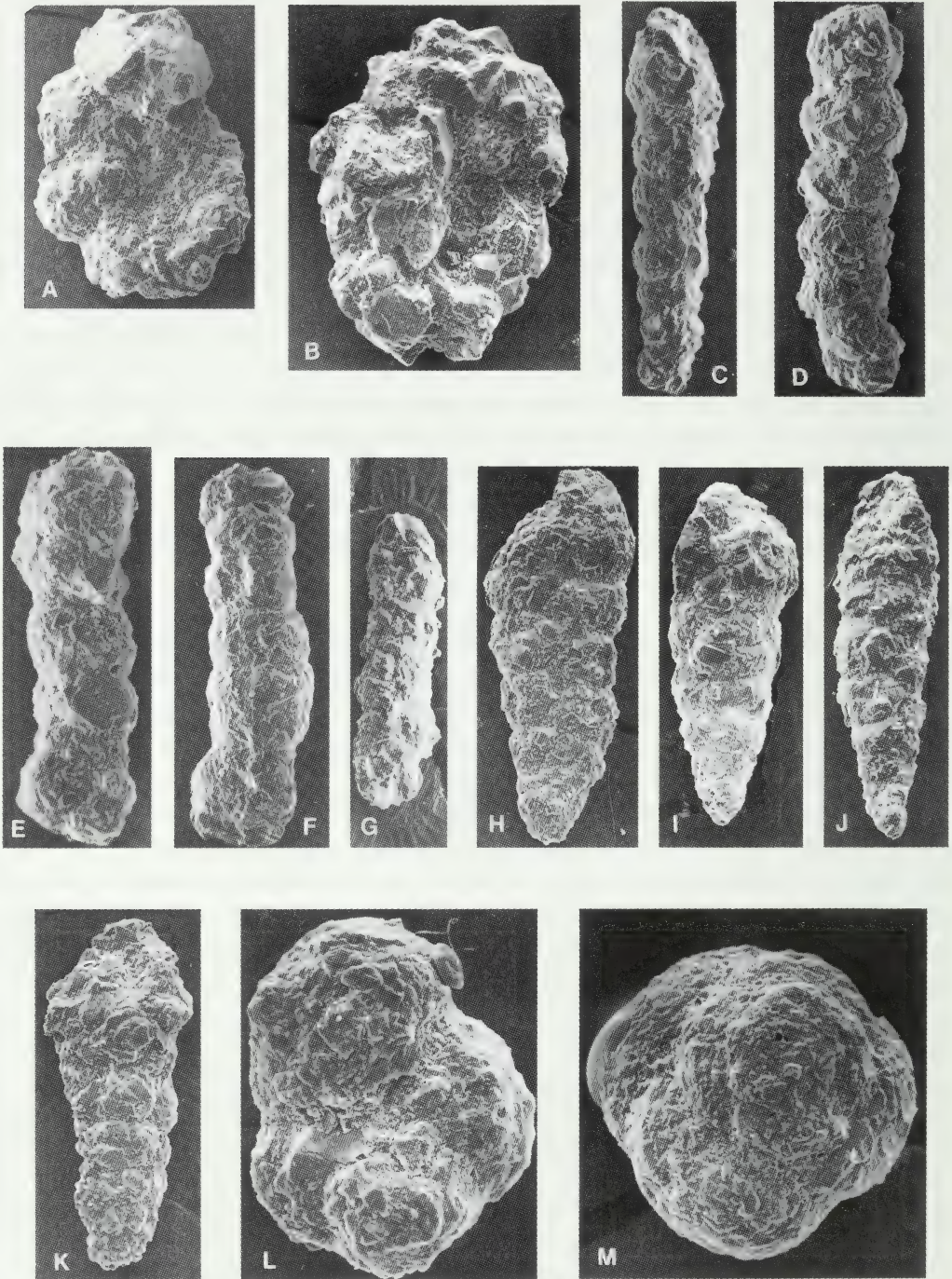


Figure 31.

*Ammobaculites* spp.

## Remarks

The majority of *Ammobaculites* tests from the Sundays River Formation are either deformed or damaged to such an extent that a specific identification is not possible. *Ammobaculites* spp. range from Biozone D to Biozone I in a wide range of environments, including marginal marine and reduced-salinity (?estuarine) biofacies.

Genus *Sculptobaculites* Loeblich & Tappan, 1984*Sculptobaculites goodlandensis* (Cushman & Alexander, 1930)

## Figs 31A–B

*Ammobaculites goodlandensis* Cushman & Alexander, 1930: 8, pl. 2 (figs 7–8). Tappan, 1940: 96, pl. 14 (figs 8a–b, 9). Tappan, 1943: 481, pl. 77 (fig. 9a–b). Loeblich & Tappan, 1949: 250, pl. 46 (fig. 14a–b). Bartenstein & Brand, 1951: 271, pl. 3 (fig. 49a–b). Crespin, 1963: 39, pl. 9 (figs 1–4). Bartenstein *et al.* 1966: 139, pl. 1 (figs 1–2).

*Sculptobaculites goodlandensis* (Cushman & Alexander). Loeblich & Tappan, 1988: 76, pl. 60 (figs 5–6, 12–16).

## Remarks

There are substantial differences in authors' illustrations of this species (see references above), the most notable being the variation in grain size of the test wall. Cushman & Alexander (1930) noted that the periphery of the species was 'broad and truncate', although not all tests subsequently referred to this species exhibit the feature. Sundays River Formation tests possess wide, but rounded, margins to the test, with the periphery sometimes strongly lobate, a trait that appears to depend on the coarseness of the grains used to construct the test. Most tests are as illustrated, but occasional ones display one or two uncoiled, rather globular chambers, which are rectilinear in arrangement. All Alga

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Fig. 31 (see facing page). A–B. *Sculptobaculites goodlandensis* (Cushman & Alexander). A. SAM-PQ-MF1173, side view, Uitenhage to Graaff-Reinet Road outcrop sample 11464 (Bb), F83. × 38. B. SAM-PQ-MF1174, side view, MV 1/79, 480–490 m (Bb), F661. × 79. C–G. *Ammobaculites parvispira* Ten Dam. C. SAM-PQ-MF1175, side view, AL 1/69, 1 960 feet (VII), F476. × 67. D. SAM-PQ-MF1176, side view, AL 1/69, 2 060 feet (VIII), F489. × 48. E. SAM-PQ-MF1177, side view, AL 1/69, 2 130 feet (VIII), F493. × 101. F. SAM-PQ-MF1178, side view, AL 1/69, 4 440 feet (A), F556. × 65. G. SAM-PQ-MF1179, side view, Uitenhage to Graaff-Reinet Road outcrop sample 11464 (Bb), F84. × 89. H–K. *Textularia zoetgeneugdia* sp. nov. H. Holotype, SAM-PQ-MF1181, side view, Zoetgeneugd Cliff outcrop sample 11450 (Bb), F248. × 97. I. Paratype, SAM-PQ-MF1182, side view, Zoetgeneugd Cliff outcrop sample 11450 (Bb), F246. × 76. J. Paratype, SAM-PQ-MF1183, side view, Zoetgeneugd Cliff outcrop sample 11450 (Bb), F249. × 92. K. Paratype, SAM-PQ-MF1184, oblique side view, Zoetgeneugd Cliff outcrop sample 11450 (Bb), F247. × 93. L–M. *Ammoglobigerina* cf. *A. globigeriniformis* (Parker & Jones). L. SAM-PQ-MF1190, ventral view, AL 1/69, 1 570 feet (VI), F434. × 220. M. SAM-PQ-MF1191, dorsal view, AL 1/69, 2 080 feet (VIII), F490. × 164.



Basin tests are coloured a rich and deep red-brown and, when well preserved and free of sediment, have a distinctive appearance.

### Occurrence

Cushman & Alexander (1930) described *Ammobaculites goodlandensis* from the Goodland Formation (Albian) of the southern United States. Later records include: Middle Cenomanian Grayson Formation (Tappan 1940), Late Albian Duck Creek Formation (Tappan 1943), and the Albian Walnut Formation (Loeblich & Tappan 1949), all of Texas and Oklahoma, U.S.A.; Aptian–Albian Lower Wilgunya Formation, Great Artesian Basin, Australia (Crespin 1963); Late Valanginian of north-western Germany (Bartenstein & Brand 1951); and possibly Late Aptian–Early Albian Maridale Formation of Trinidad (Bartenstein *et al.* 1966).

### Stratigraphic range in the Sundays River Formation

Confined to the Late Valanginian (Biozone Bb). One or two possible occurrences have been recorded in Biozone Ba. The species has not been found in South Africa outside of the Sundays River Formation in the onshore Algoa Basin. *Sculptobaculites goodlandensis* is typical of lowered oxygen, near-normal salinity, continental-shelf environments, and does not occur close to shore in any facies.

Subfamily Placopsilinae Rhumbler, 1913

Genus *Placopsilina* d'Orbigny, 1850

*Placopsilina cenomana* d'Orbigny, 1850

Fig. 32

*Placopsilina cenomana* d'Orbigny, 1850b: 185, no. 758. Loeblich & Tappan, 1964: C247, fig. 159 (nos 1–2). Winter, 1970: 9, pl. 1 (figs 24–31), pl. 2 (figs 38–40), text-fig. 8.

### Remarks

A single specimen of *Placopsilina* was found. It is low, spreading and strongly compressed, and appears referable to *Placopsilina cenomana*. It shows close similarities with the examples illustrated by Winter (1970) from the Early Kimmeridgian of southern Germany. The initial coil of the Sundays River example is very incomplete. The test is attached to a fragment of mollusc (?bivalve) shell and possesses a finely agglutinated wall of small quartz particles.

Other illustrations of *Placopsilina cenomana* are of distinctly different forms—see Chapman (1892a, pl. 6 (fig. 4)) and Espitalié & Sigal (1963, pl. 4 (fig. 5)), as *Placopsilina* cf. *cenomana*), for example. Because of the wide variety of forms assigned to this name, its stratigraphic range remains unclear.

### Stratigraphic range in the Sundays River Formation

The single specimen is from the Late Valanginian Biozone Bb.



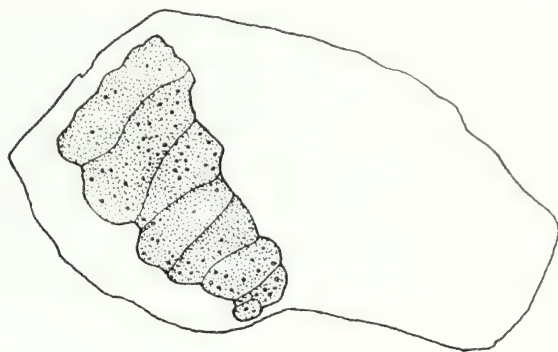


Figure 32.

*Placopsilina cenomana* d'Orbigny. SAM-PQ-MF1180, surface view,  
MV 1/79, core 2, 544.0 m (Bb).  $\times 103$ .

Family **Textulariidae** Ehrenberg, 1838  
Subfamily Textulariinae Ehrenberg, 1838  
Genus *Textularia* DeFrance, 1824  
***Textularia zoetgeneugdia*** sp. nov.  
Figs 31H-K

### Diagnosis

A slender, elongate *Textularia* with up to seven pairs of chambers, broadly rounded test periphery, weakly depressed, almost horizontal sutures, and a moderately coarse quartz grain size in the test wall.

### Etymology

Adjective, from its occurrence at Zoetgeneugd Cliff outcrop.

### Material

*Holotype* (Fig. 31H). MF 1181, SOEKOR negative F248.

*Paratypes* (Figs 31I-K). MF1182 to MF1184, SOEKOR negatives F246, F249, and F247 and SAM-MF1185 to MF1189, five additional specimens from sample 11450, Zoetgeneugd Cliff.

### Stratum typicum

Zoetgeneugd Cliff, basal Biozone Bb, Late Valanginian, Sundays River Formation.

### Locus typicus

Zoetgeneugd Cliff sample 11450.

### Description

Test elongate, slender, slightly compressed, with maximum width and depth of test at or near final chamber. Test periphery usually sub-linear, very faintly lobate in the later

part of the test. Test margin broadly rounded in cross-section. Chambers arranged biserially throughout, in up to seven pairs, and closely appressed. Chambers increase slowly and regularly in size as added. Later chambers are a little wider than high, and are slightly inflated. Sutures initially indistinct, flush, later becoming weakly depressed, and sub-horizontally aligned. The median suture forms a neatly constructed zigzag. Aperture interio-marginal, a low, slit-like opening at the base of the last-formed chamber, centrally placed and terminating on either side, well short of the test margins. The aperture is evident only in a few specimens. Apical point of the test rounded and unornamented, but usually this part of the test is damaged or broken off. Test wall fairly rough, composed of scattered moderate to coarse-grained quartz particles set in finer quartz material and cement.

### Remarks

*Textularia zoetgeneugdia* appears to be confined to shallow, marginal marine, well-oxygenated, near-normal salinity environments. The species is unusual for Early Cretaceous *Textularia* in possessing such an elongate, compact shape. It differs from *T. anacooraensis* Crespin (1953, 1963) from the Aptian–Albian Lower Wilgunya Formation of the Great Artesian Basin, Australia, in possessing more nearly horizontal sutures, but the overall shape of the test is similar. *Textularia zoetgeneugdia* differs from *T. bettenstaedti* Bartenstein & Oertli (1977) (see also Bartenstein & Kovatcheva 1982), from the Early Cretaceous of Bulgaria, north-west Germany and elsewhere in Europe, in lacking the ‘coal dust’ (?graphite) particles over the lower parts of the chambers and the sutures, and in being a little more compressed, although the forms are clearly similar. The chambers of *T. zoetgeneugdia* are lower and less inflated, and the early part of the test more tapering than *T. minuta* Berthelin (see Reuss 1863, pl. 9 (fig. 11a–b); Magniez-Jannin 1975, pl. 3 (fig. 35–36)), a species typical of the western European Albian. *Textularia foeda* Reuss, which ranges from the Late Hauterivian to the Middle Albian of north-west Germany (Bartenstein & Bettenstaedt 1962), possesses about eleven distinctly inflated chambers with ?graphite speckling and oblique, depressed sutures. Tests assigned to *T. foeda* occur in the Late Aptian to Middle Cenomanian of the South African southern offshore region, and are markedly different in chamber shape, test outline, depression and angle of sutures, and number of chambers from *T. zoetgeneugdia*.

### Stratigraphic range in the Sundays River Formation

Apparently confined to the Late Valanginian (earliest Biozone Bb).

### Supplementary note

One of the reviewers (W. R.) of this publication has pointed out that *Textularia zoetgeneugdia* sp. nov. is better placed in the essentially Mesozoic genus *Textulariopsis* Banner & Pereira (1981) than in *Textularia*. *Textulariopsis* was characterized by these authors as possessing imperforate solid walls, whereas *Textularia* was distinguished by perforate test walls, and was considered to range from the Eocene to the present day. As far as can be established, *Textularia zoetgeneugdia* tests are imperforate, and the

author agrees that this species should more properly be *Textulariopsis zoetgeneugdia* sp. nov. However, through circumstances beyond anyone's control, it has proved impossible to amend some figures containing the original name (Figs 20 and 26 in particular), so that to keep the text and figures coherent, the original text has been retained. *Textulariopsis zoetgeneugdia* differs from *Textulariopsis texhomensis* Loeblich & Tappan (1982: 68, pl. 2 (figs 38–39)), described from the Late Albian Duck Creek Formation of Texas, in lacking the inflated, rather globular chambers of the later part of the test, and the corresponding strongly depressed sutures and lobate test margin, as well as lacking the long, slender taper to the initial portion of the test.

Family **Trochamminidae** Schwager, 1877

Subfamily Trochammininae Schwager, 1877

Genus *Ammoglobigerina* Eimer & Fickert, 1899

*Ammoglobigerina* cf. *A. globigeriniformis* (Parker & Jones, 1865)

Figs 31L–M

see *Lituola nautiloidea* Lamarck *globigeriniformis* Parker & Jones, 1865: 407, pl. 15 (figs 46–47), (?also pl. 17 (figs 96–98)).

see *Haplophragmium globigeriniforme* (Parker & Jones). Chapman, 1892a: 324, pl. 5 (fig. 16).

*Trochammina globigeriniformis* (Parker & Jones). Lloyd, 1959: 317, pl. 54 (fig. 31), text-fig. 5c.

Wernli, 1971: 315, pl. 8 (figs 4, 9a–c). Kuznetsova, 1974: pl. 1 (fig. 3a–b). Barnard & Shipp, 1981: 9, pl. 1 (figs 11–12). Coleman, 1981: 114, pl. 6.2.1 (fig. 11).

'*Trochammina*' sp. cf. *T. globigeriniformis* (Parker & Jones). Masiuk & Viña, 1987: 292, pl. 2 (figs 4–8, 11).

### Remarks

Small specimens of *Ammoglobigerina* occur in lowered oxygen sequences of the Sundays River Formation, and seem best assigned to *Ammoglobigerina* cf. *A. globigeriniformis*. These are part of a well-known group, occurring sporadically through most of the north-west European Jurassic, but less recorded from the Early Cretaceous. The Barremian to Aptian *Trochammina gerochi* Bartenstein & Kovatcheva (1982) may fall within this *globigeriniformis* group. The taxonomic status of the group is confused, since *Trochammina globigeriniformis* was first described from present-day sediments of the North Atlantic Ocean, and it is not clear whether the Jurassic and Holocene forms are conspecific.

Parker and Jones (1865) illustrated several rather different specimens under this name, and the refigured lectotype illustrated by Loeblich & Tappan (1964, fig. 173 (no. 2a–c)) is of a very different form than the Jurassic and Sundays River Formation examples. Loeblich & Tappan (1964) based their understanding of the species on the specimen illustrated by Parker & Jones (1865, pl. 17 (fig. 96)), and thus it appears that the Parker & Jones specimens figured as pl. 15 (figs 46–47) are possibly a separate unnamed species. The latter illustrations compare best with the Jurassic and Sundays River tests.

The Sundays River Formation tests can be divided into two groups: those with a high



trochospiral coil, which may almost attain the height of tests of *Gravellina* on occasion, and those with a much lower trochospire, such as that illustrated in Figure 31M.

Said & Barakat (1958) described *Trochammina bartensteini* from the Bathonian of Gebel Maghara. They remarked that this species may be the same as Bartenstein & Brand's (1937) *T. globigeriniformis* from the German Lias and Dogger. It differs from Holocene tests of the latter species (*sensu lato*) in its smaller, more depressed test and its less lobate periphery. The illustrations of *T. bartensteini* given by Said & Barakat (1958) are not too clear, but this name may prove to be available for Jurassic '*Trochammina globigeriniformis*' tests. The similar *T. canningensis* Tappan (1955) from the Jurassic of Alaska possesses more chambers (four to seven) in the final whorl, and the shape of the test is different.

Masiuk & Viña (1987) described specimens of this group from the Late Valanginian and Early Hauterivian of the Katterfeld Formation of Chubut, Argentina. The Sundays River Formation tests are very similar, but their peripheries are generally less strongly lobate. However, in many tests, having been variably distorted as a result of compaction, this feature is difficult to quantify. None of these Argentinian or South African tests show similarity to the species *Ammoglobigerina praeglobigeriniformis*, described by Soliman (1972) from the Late Turonian and Coniacian of the Russian Carpathians. Notable differences in the Russian species are the narrow umbilicus, and the more appressed, less lobate chambers, particularly evident in the final whorl.

### Occurrence

Lias and Dogger (Bartenstein & Brand 1937; Coleman 1981), and Late Jurassic (Lloyd 1959; Barnard & Shipp 1981) of north-west Europe.

### Stratigraphic range in the Sundays River Formation

*Ammoglobigerina* cf. *A. globigeriniformis* occurs sporadically through most of the sequence (Biozones Bb to I), but is at its commonest in lowered-oxygen environments, particularly through the CK 1/68 section, in the northern Sundays River Trough. There appear to be no differences in the stratigraphic ranges of the high- and low-spined tests.

Genus *Trochammina* Parker & Jones, 1859  
*Trochammina* cf. *T. inflata* (Montagu, 1808)  
 Figs 33A–D

see *Nautilus inflatus* Montagu, 1808: 81, pl. 18 (fig. 3).

see *Trochammina inflata* (Montagu). Bartenstein & Brand, 1951: 280, pl. 4 (figs 97a–c, 98a–c).

### Remarks

The various forms of *Trochammina* from the Jurassic and Cretaceous that have been referred to the extant marsh species *Trochammina inflata* are almost certainly not conspecific, but morphologically they are very close. The Sundays River Formation specimens appear closest to the illustrated specimen given by Bartenstein & Brand (1951,

pl. 4 (fig. 97a–c)). All of these tests contain four or five inflated chambers in the final whorl, a wide depressed umbilicus, straight or weakly curved, radiate, depressed sutures on the ventral side and oblique, backward-curving, depressed sutures on the dorsal side. Tests similar to the Sundays River shells occur also in the Portlandian Colchester Member of the Uitenhage Trough, onshore Algoa Basin (McMillan 1980).

#### *Stratigraphic range in the Sundays River Formation*

This form occurs intermittently in the later Early and Late Hauterivian (Biozones VIII to I). The species is typical of near-normal marine conditions on the middle to outer shelf, in contradistinction to true extant *Trochammina inflata*, which is confined to mudflats and marshes with low salinities.

#### *Trochammina sundaysriverensis* sp. nov.

Figs 33E–H, 34A–C

#### *Diagnosis*

A species of *Trochammina* characterized by a concavo-convex or plano-convex test, with six to eight inflated chambers in the final whorl, oblique depressed dorsal sutures, weakly curved, radiate, depressed ventral sutures, and a broad, shallow umbilicus.

#### *Material*

*Holotype* (Figs 33E, 34A–C). MF1196, SOEKOR negative F123.

*Paratypes* (Figs 33F–H). MF1197 to MF1199, three specimens, SOEKOR negatives F93, F126, and F306.

#### *Etymology*

From its occurrence in the Sundays River Formation.

#### *Stratum typicum*

Biozone I, Late Hauterivian, Sundays River Formation.

#### *Locus typicus*

AL 1/69, cuttings sample at 520 feet.

#### *Description*

Test concavo-convex or plano-convex in overall shape, with dorsal side weakly concave or flat, and ventral side strongly convex. Test outline circular, with a distinctly lobate periphery; in cross-section the margin is broadly rounded, but oriented slightly towards the dorsal side. Chambers arranged in a low trochospiral coil, increasing in size slowly and steadily as added, with from six to eight in the final whorl. Initial chambers flush, later chambers in final whorl distinctly inflated. Sutures initially indistinct, flush; later sutures distinct, depressed: on dorsal side weakly curved or straight, rather oblique, and on ventral straight to weakly curved, radiate. Aperture usually obscured, but



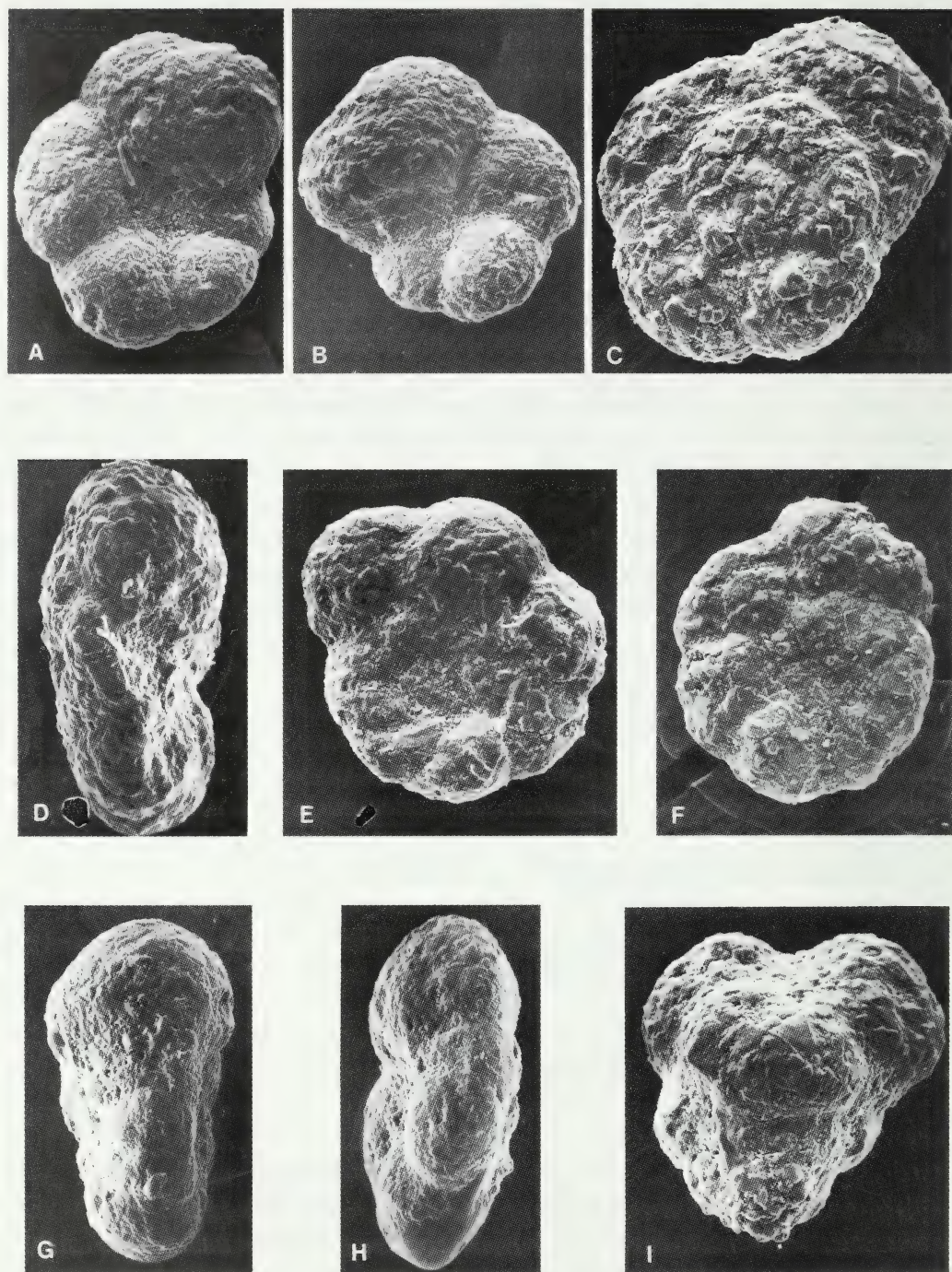


Figure 33.



apparently partly interio-marginal, at base of the terminal face of the last-formed chamber, umbilical to extra-umbilical in position, not reaching as far as the test periphery; a low elongate slit in form. Umbilicus wide, shallow. Surface of test variable, moderately smooth to rather rough, composed of small angular quartz grains and finer material, set in moderate quantities of cement.

### Remarks

*Trochammina sundaysriverensis* is most readily distinguished by its flat or concave dorsal side. In this respect it shows some similarity to *T. subinflata*, described by Crespin (1963) from the Early Cretaceous of the Great Artesian Basin. However, it lacks the strongly inflated final chamber and rapid increase in chamber size of that species, but possesses rather more chambers in the final whorl. It does not display the angled, lobulate periphery and convex dorsal, concave ventral side of *T. limbata* (Chapman), first described from the Aptian Bargate Beds of southern England (Chapman 1894d), and later from the Hauterivian of the Netherlands (Ten Dam 1946). *Trochammina sundaysriverensis* also shows some slight similarities to some specimens of *Trochammina* aff. *T. latta* Loeblich & Tappan, as figured by Damotte & Magniez-Jannin (1973) and Magniez-Jannin (1975) from the Aptian and Albian of France. However, these French shells exhibit a rapid increase in chamber size, are biconvex, and possess backward curved dorsal sutures. *Trochammina neocomiana* Mjatluk, as described by Espitalié &

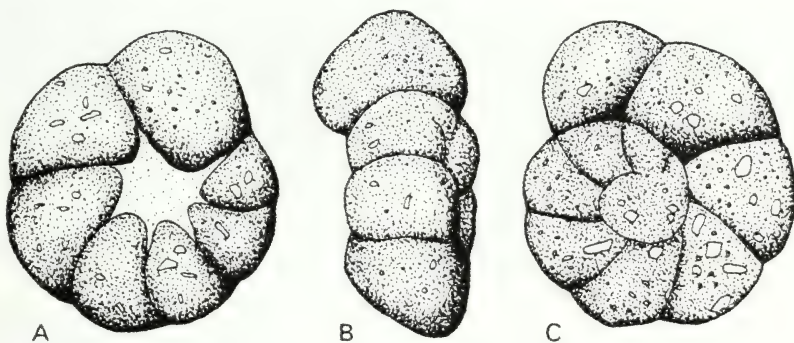


Figure 34.

*Trochammina sundaysriverensis* sp. nov. A–C. Holotype, SAM–PQ–MF1196, AL 1/69, 520 feet (I). A. Ventral view. B. Side view. C. Dorsal view. All  $\times 144$ .

Fig. 33 (see facing page). A–D. *Trochammina* cf. *T. inflata* (Montagu). A. SAM–PQ–MF1192, ventral view, AL 1/69, 1 210 feet (IV), F348.  $\times 92$ . B. SAM–PQ–MF1193, ventral view, AL 1/69, 760 feet (II), F217.  $\times 78$ . C. SAM–PQ–MF1194, dorsal view, AL 1/69, 610 feet (II), F182.  $\times 123$ . D. SAM–PQ–MF1195, side view, AL 1/69, 1 360 feet (IV), F372.  $\times 124$ . E–H. *Trochammina sundaysriverensis* sp. nov. E. Holotype, SAM–PQ–MF1196, dorsal view, AL 1/69, 520 feet (I), F123.  $\times 126$ . F. Paratype, SAM–PQ–MF1197, dorsal view, AL 1/69, 490 feet (I), F93.  $\times 152$ . G. Paratype, SAM–PQ–MF1198, side view, AL 1/69, 520 feet (I), F126.  $\times 153$ . H. Paratype, SAM–PQ–MF1199, side view, AL 1/69, 1 030 feet (III), F306.  $\times 135$ . I. *Verneuilina secreta* sp. nov., paratype, SAM–PQ–MF1200, side view, AL 1/69, 940 feet (III), F275.  $\times 133$ .

Sigal (1963) from Cenozoone D (Late Portlandian to Early Valanginian) of the Majunga Basin, Madagascar, although rather plano-convex with a flat dorsal side, reveals a very convex ventral side, remarkably globular chambers, and a narrow, deep umbilicus.

*Stratigraphic range in the Sundays River Formation*

Late Hauterivian (late Biozone IV to Biozone I). As with most *Trochammina* tests from the Sundays River Formation, *Trochammina sundaysriverensis* is found only in the more distal localities, well away from marginal marine environments.

*Trochammina* spp.

*Remarks*

Scattered tests referable to *Trochammina* occur throughout most of the Sundays River Formation sequence, but they cannot be identified to specific level either because of damage or post-depositional distortion of tests.

Family **Verneuilinidae** Cushman, 1911

Genus *Verneuilina* d'Orbigny, 1839

***Verneuilina secreta*** sp. nov.

Figs 33I, 35A–D

*Diagnosis*

A conical species of *Verneuilina* characterized by broadly rounded test peripheries, subglobular chambers usually arranged in three vertical columns, and a moderately roughened test wall containing angular quartz grains.

*Etymology*

*Secretus*, -a, -um (L.): adjective from its distinct morphology, and from being one of very few Southern Hemisphere *Verneuilina* species, its remoteness and rarity.

*Material*

*Holotype* (Fig. 35A). MF1201, SOEKOR negative F173.

*Paratypes* (Figs 33I, 35B–D). MF1200, MF1202 to MF1204, four specimens, SOEKOR negatives F275, F326, F327, and F427.

*Stratum typicum*

Biozone II, Late Hauterivian, Sundays River Formation.

*Locus typicus*

AL 1/69, cuttings sample at 580 feet.

*Description*

Test conical, with maximum width at level of last-formed chambers. Periphery of test

initially continuous, later strongly lobate; in cross-section test outline is broadly rounded. Chambers triserially arranged throughout, usually in three vertically aligned columns, although occasional tests show some distortion at particular levels to this arrangement. Chambers subglobular, with little overlap on previous ones, much inflated in the final portion of the test, increasing slowly and regularly in size as added; generally twice as wide as high; arranged in five to six whorls. Sutures initially indistinct, flush, later becoming distinct, depressed, with the spiral suture almost horizontally aligned. Aperture interio-marginal, at the base of the final chamber, in form apparently a low elongate slit, but not well preserved in any of the specimens. Apical portion of test broadly rounded, through usually damaged. Surface of test roughened; test wall composed of coarser angular quartz grains with finer material and relatively little cement.

#### Remarks

The specimen shown in apical view is somewhat distorted, and in side view is clearly triserial, despite the rather polyserial form suggested in Figure 35C. Tests of *Verneuilina secreta* are distinct from most Northern Hemisphere species assigned to the genus, principally in the globular chamber form and the broad and rounded, rather than acutely angled, margins of the test. For this reason, there must exist some doubt as to whether this is a true species of *Verneuilina*. From the size of tests, and the conical test outline, these specimens cannot be considered juveniles of another genus, such as *Verneuilinoides*. Tests of *Verneuilinoides neocomiensis* (Mjatliuk) and *Verneuilinoides inaequalis* Bartenstein & Brand, typical of the European Early Cretaceous, are very nearly parallel-sided when adult: in contrast, *Verneuilina secreta* remains distinctly conical.

*Verneuilina secreta* is one of several species in the South African Early Cretaceous which perhaps constitute a lineage of forms in the austral province. Similar species are known from the Barremian and the Late Aptian to Early Albian of the southern offshore of South Africa. The only South African species that is strongly triangular in cross-section is *Verneuilina howchini* Crespin, which is confined to the Early Barremian to Early Aptian of the southern offshore.

#### Stratigraphic range in the Sundays River Formation

Confined to the Late Hauterivian, Biozones VII to II. The species is found in the more distal intersections of the Sundays River Formation.

*Verneuilina* sp. B  
Fig. 35E

#### Remarks

One *in situ* specimen of *Verneuilina* occurs in Late Valanginian Biozone A. It is clearly related to *Verneuilina secreta* sp. nov. in its test morphology, but it is more slender and less conical than the Late Hauterivian species. For the present it is regarded as a separate species.



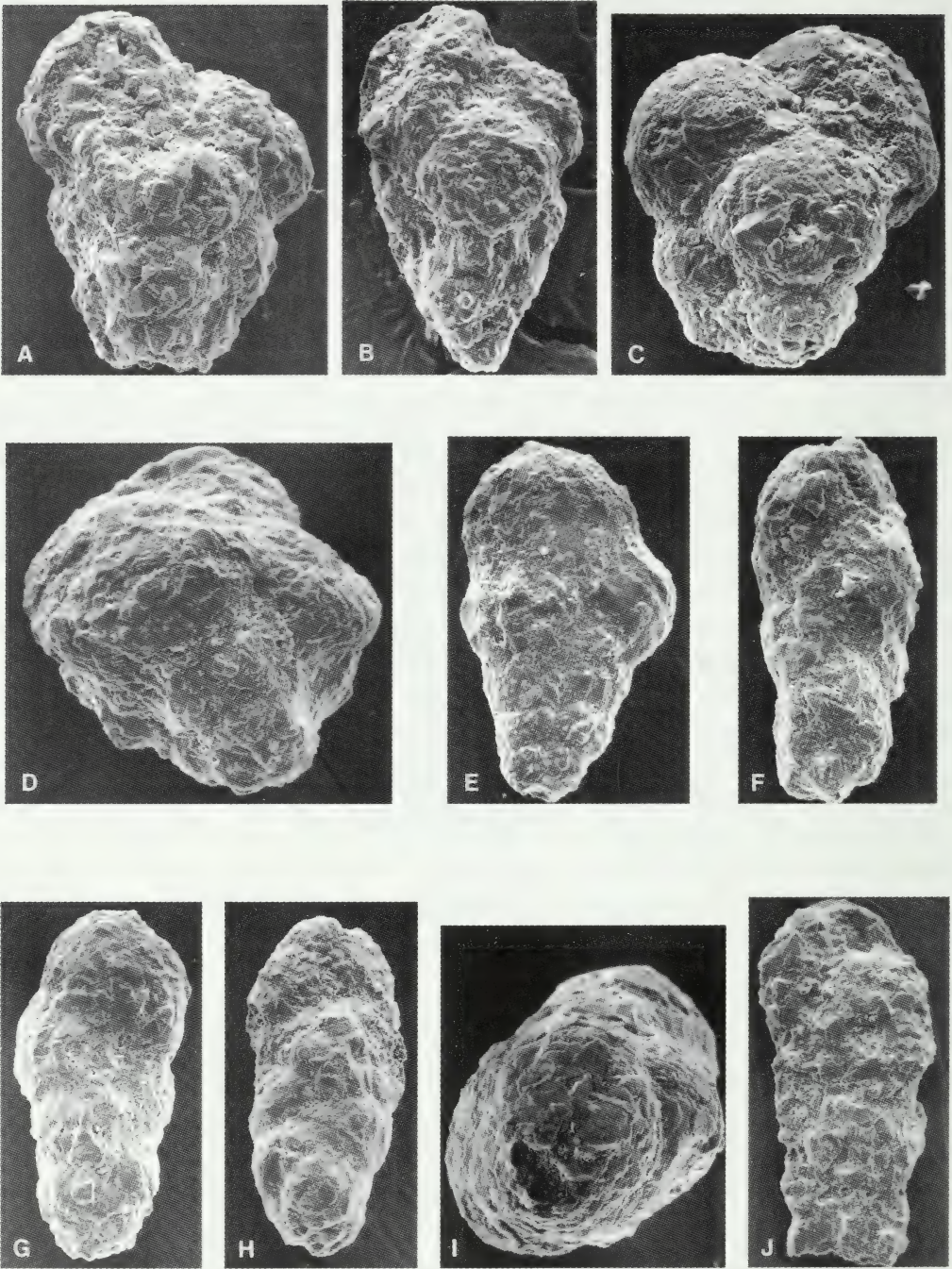


Figure 35.

Genus *Gaudryinella* Plummer, 1931

*Gaudryinella alexandria* sp. nov.

Figs 35F–I

### Diagnosis

An elongate, rather gracile species of *Gaudryinella* with initial triserial chambers, later inflated biserial to cuneate, subglobular chambers, and with depressed sutures and terminal aperture.

### Etymology

Noun in apposition; from borehole AL 1/69, named for the magisterial district of Alexandria, in which the borehole was drilled.

### Material

*Holotype* (Fig. 35G). MF1207, SOEKOR negative F271.

*Paratypes* (Figs 35F, H, I). MF1206, MF1208, MF1209, three specimens, SOEKOR negatives F298, F163, and F297.

### Stratum typicum

Late Hauterivian Biozone III of the Sundays River Formation.

### Locus typicus

AL 1/69, cuttings sample at 910 feet.

### Description

Test elongate, moderately gracile, almost parallel-sided, with maximum width usually at or near level of final pair of chambers, and compressed. Test periphery variably lobate; in cross-section test margins are broad and well rounded. Chambers initially triserially arranged, increasing rapidly in size as added, arrayed in three whorls; subglobular in form and flush to inflated in external view. Later chambers biserially arranged, increasing in size steadily as added, with final few chambers cuneate and about as wide as high. The chambers overlap previous ones to some degree, and the final chamber is often distinctly larger than the earlier ones. The initial triserial part constitutes about one quarter of the

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Fig. 35 (see facing page). A–D. *Verneuilina secreta* sp. nov. A. Holotype, SAM–PQ–MF1201, side view, AL 1/69, 580 feet (II), F173.  $\times 103$ . B. Paratype, SAM–PQ–MF1202, side view, AL 1/69, 1 090 feet (III), F326.  $\times 138$ . C. Paratype, SAM–PQ–MF1203, apical view, AL 1/69, 1 090 feet (III), F327.  $\times 140$ . D. Paratype, SAM–PQ–MF1204, apertural view, AL 1/69, 1 570 feet (VI), F427.  $\times 132$ . E. *Verneuilina* sp. B, SAM–PQ–MF1205, side view, MV 1/79, 310–320 m (A), F654.  $\times 121$ . F–I. *Gaudryinella alexandria* sp. nov. F. Paratype, SAM–PQ–MF1206, side view, AL 1/69, 1 000 feet (III), F298.  $\times 126$ . G. Holotype, SAM–PQ–MF1207, side view, AL 1/69, 910 feet (III), F271.  $\times 120$ . H. Paratype, SAM–PQ–MF1208, side view, AL 1/69, 520 feet (I), F163.  $\times 102$ . I. Paratype, SAM–PQ–MF1209, apertural view, AL 1/69, 1 000 feet (III), F297.  $\times 260$ . J. *Dorothia* sp. A, SAM–PQ–MF1210, side view, AL 1/69, 2 360 feet (VIII), F499.  $\times 126$ .



total test height. Sutures initially indistinct, flush, becoming clearer, depressed, lightly and uniformly curved, and reaching the test periphery at an angle of from thirty to fifty degrees to horizontal. Aperture terminal, sited at the apex of the last-formed chamber; in shape an elongate-ovate to sub-circular opening, and unornamented. Test surface lightly roughened: test wall composed of moderate sized, angular quartz grains set in medium quantities of cement.

### Remarks

*Gaudryinella alexandria* differs from *G. sherlocki* Bettenstaedt (1952), from the Barremian to Early Albian of north-west Europe, in its cuneate, rather than regularly biserial later part of the test, and in its more slender form with compressed, subglobular chambers. Comparative illustrations of *G. sherlocki* are given by Sherlock (1914, pl. 18 (fig. 2)), Bettenstaedt (1952, pl. 1 (figs 1–5)), Bartenstein & Bettenstaedt (1962, pl. 38 (fig. 14), table 18 (part 2)), Bartenstein *et al.* (1966, pl. 1 (figs 38–40)), and Hart *et al.* (1981, pl. 7.2 (figs 4–5)). Hart *et al.* (1981) noted that what variation is seen in the species is due to distortion of tests after burial. *Gaudryinella alexandria* lacks the separated, globular chambers of tests of *Gaudryinella* aff. *sherlocki* as described and illustrated by Crittenden (1983: 22, pl. 2 (figs 22–25)) from the Early Aptian of southern England. The forms illustrated as *Gaudryinella* aff. *sherlocki* by Damotte & Magniez-Jannin (1973) exhibit a different chamber morphology in the later part of the test than either *G. sherlocki* or *G. alexandria*. *Gaudryinella alexandria* lacks the fully rectilinear arrangement of uniserial chambers seen in tests of *G. tealbyensis* Bartenstein (1956), and also does not show the nearly circular cross-section of this English Hauterivian species. It differs from *G. pusilla* Magniez-Jannin (1975) in wanting the nearly globular, strongly inflated chambers of the terminal part of the test.

### Stratigraphic range in the Sundays River Formation

Late Hauterivian (upper Biozone IV to Biozone I). Restricted to outer shelf, near normal marine environments.

### Genus *Dorothia* Plummer, 1931 *s.l.*

A variety of forms are here allocated to the genus *Dorothia* *s.l.* *Dorothia* sp. A and *Dorothia inglesidensis* sp. nov. are narrow, almost parallel-sided forms that are the earliest species of a series that ranges through the South African Cretaceous from the Early Hauterivian to the top of the Santonian. These forms typically possess a conical polyserial initial portion (four or five chambers to the whorl), circular in cross-section, that occupies a quarter or a third of the total test height, followed by a long, regular, biserial portion, with the typical *Dorothia* aperture of a low interio-marginal slit at the base of the final chamber. The test wall is dominantly composed of agglutinated material, and calcareous matter, apart from cement, is at a minimum. It has not yet proved possible to determine if the test wall is canaliculate in *Dorothia* sp. A., *Dorothia inglesidensis* sp. nov., or in other members of this group.



Desai & Banner (1987) emended and expanded on the two genera *Dorothia* and *Marssonella*, and it thus seems that narrow, parallel-sided forms fall well outside the strict definitions of emended *Dorothia* and *Marssonella*, as well as *Praedorothia* and *Protomarssonella*, presented by these authors. Loeblich & Tappan (1988) also did not distinguish such forms, reflecting perhaps the wide interpretation given by them previously to *Dorothia* (Loeblich & Tappan 1964). For the moment, *Dorothia* is thus here considered *sensu lato*, although subdivision is clearly warranted. The third species encountered in the Sundays River Formation, *Dorothia australis* sp. nov., can confidently be referred to *Dorothia* s.s., as re-defined by Desai & Banner (1987).

*Dorothia* sp. A  
Figs 35J, 36A–D

*Remarks*

Small numbers of poorly preserved, apparently rather distorted tests referable to *Dorothia* occur in the Hauterivian. These are elongate, with a long, gently tapering polyserial portion of the test. Later biserial chambers are weakly inflated, increasing in width slowly to a maximum at the final pair of chambers. The aperture is a narrow interio-marginal slit at the base of the final chamber, and usually sited in a slight recess. It is possible that poorly preserved tests of the following species, *Dorothia inglesidensis* sp. nov. have been included here, since their stratigraphic ranges overlap and their test morphologies are not dissimilar. Because of their poor preservation, examples of *Dorothia* sp. A are not easily compared to other species from elsewhere in the world. The test illustrated as *Spiroplectammina cushmani* Crespin by Beer (1970, pl. 1 (fig. 5)) seems to lack an initial coil, unlike Crespin's species, and is probably referable to *Dorothia* sp. A, since *Spiroplectammina* or *Spiroplectinella* species are entirely lacking in the extensive microfaunas examined at SOEKOR from the Sundays River Formation.

*Stratigraphic range in the Sundays River Formation*

Later Early Hauterivian to Late Hauterivian (Biozones VIII to I), middle to outer shelf.

*Dorothia inglesidensis* sp. nov.  
Figs 36E–H, 37A–D

*Textularia* sp. aff. *foeda* Beer, 1970: 9, pl. 1 (fig. 4a–b) (*non* Reuss).

*Diagnosis*

A slender, parallel-sided species of *Dorothia* with a circular cross-section, inflated and rather high chambers that are especially evident in the final pair of the test.

*Etymology*

From its occurrence in the CO 1/67, CO 2/70 and CO 3/71 boreholes, drilled adjacent to the Ingleside Cliff, just west of Colchester Cliff.



Figure 36.



*Material*

*Holotype* (Figs 36E, 37A–B). MF1215, SOEKOR negative F666.

*Paratypes* (Figs 36F–H, 37C–D). MF1216 to MF1219, four specimens, SOEKOR negatives F500, F426, and F416.

*Stratum typicum*

Biozone VI, Late Hauterivian, Sundays River Formation.

*Locus typicus*

Shallow borehole SB–9A, Core 1, 282 feet 6 inches.

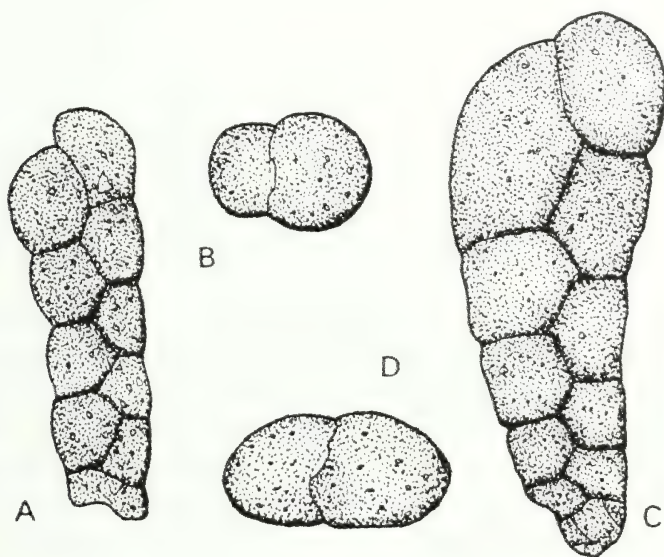


Figure 37.

*Dorothia inglesidensis* sp. nov. A–B. Holotype, SAM–PQ–MF1215, side and apertural views respectively, shallow borehole SB–9A, core 1, 282 feet 6 inches (II).  $\times 113$ . C–D. Paratype, SAM–PQ–MF1219, side and apertural views respectively, showing initial portion of test, SH 1/74, 90 m (VI).  $\times 127$ .

Fig. 36 (see facing page). A–D. *Dorothia* sp. A. A. SAM–PQ–MF1211, side view, AL 1/69, 2 410 feet (VIII), F513.  $\times 88$ . B. SAM–PQ–MF1212, edge view, AL 1/69, 2 470 feet (VIII), F514.  $\times 88$ . C. SAM–PQ–MF1213, edge view, AL 1/69, 940 feet (III), F276.  $\times 137$ . D. SAM–PQ–MF1214, edge view, AL 1/69, 1 480 feet (IV), F377.  $\times 123$ . E–H. *Dorothia inglesidensis* sp. nov. E. Holotype, SAM–PQ–MF1215, side view, shallow borehole SB–9A, core 1, 282 feet 6 inches (II), F666.  $\times 137$ . F. Paratype, SAM–PQ–MF1216, side view, AL 1/69, 2 360 feet (VIII), F500.  $\times 112$ . G. Paratype, SAM–PQ–MF1217, side view, AL 1/69, 1 570 feet (VI), F426.  $\times 98$ . H. Paratype, SAM–PQ–MF1218, edge view, AL 1/69, 1 540 feet (VI), F416.  $\times 84$ . I–L. *Dorothia australis* sp. nov. I. Paratype, SAM–PQ–MF1220, side view, MV 1/79, 250–260 m (A), F634.  $\times 112$ . J. Paratype, SAM–PQ–MF1221, side view, AL 1/69, 4 470 feet (A), F560.  $\times 164$ . K. Holotype, SAM–PQ–MF1222, side view, MV 1/79, 90 m (X), F574.  $\times 123$ . L. Paratype, SAM–PQ–MF1223, edge view, MV 1/79, 140 m (X), F586.  $\times 156$ .



### Description

Test elongate, narrow, parallel-sided, occasionally showing maximum test width at level of last formed pair of chambers. Test periphery lobate, broadly rounded, with cross-section of adult part of test circular to sub-circular. Chambers arranged in an initial polyserial portion, with 3–4 whorls apparently of 4–5 chambers each; this part of the test tapering. Later part of test displays up to five pairs of biserially arranged chambers, increasing moderately and regularly in height as added. Later chambers inflated. Early biserial chambers are about as wide as high, whereas the later ones are one-and-a-half or two times higher than wide. The final pair of chambers is particularly high, and indicates some degree of overlap of the later chambers on earlier ones. Sutures initially rather indistinct, flush or weakly depressed, becoming distinct, depressed, and with a clear central zigzag suture; sutures reach the test periphery at a low angle of about 10 degrees; sutures straight, rarely weakly curved. Aperture interio-marginal, located at the base of the last-formed chamber, and sited at the foot of a prominent, nearly vertical interio-marginal face of the final chamber. Form of aperture a low, elongate, rather arched slit, which terminates well short of the test periphery. Surface of test lightly rugose, composed of moderate to fine-grained quartz particles, some angular, set in moderate cement.

### Remarks

None of the tests assigned to *Dorothia inglesidensis* are complete: in all cases the earliest part of the shell is missing. Occasional damaged examples of the early part occur, sufficient to gain a full understanding of the species, as illustrated in Figure 37C–D.

*Dorothia inglesidensis* differs from *D. filiformis* (Berthelin) in possessing more compact, much less globular or subglobular chambers, and a neater, tighter biserial arrangement than the latter species. Authors' interpretations of *D. filiformis* vary—compare the illustrations of Sherlock (1914, pl. 18 (fig. 4)), Chapman (1892*b*, pl. 11 (fig. 7)), Crespin (1963, pl. 16 (fig. 8)), Hart *et al.* (1981, pl. 7.1 (figs 11–12)), Bartenstein *et al.* (1966, pl. 1 (fig. 43)), and Magniez-Jannin (1975, pl. 8 (figs 1–2)), but *D. inglesidensis* is distinct from all of these. Many illustrations of *D. filiformis*, however, suggest the initial portion of the test is triserial and trilobate, although authors' descriptions may not confirm this. There is thus a possibility that some tests included under this name should be better referred to the genus *Gaudryinopsis* (see Loeblich & Tappan 1988: 133, pl. 140 (figs 26–32)). *Dorothia inglesidensis* lacks the apertural arrangement and compact polyserial portion of *D. invenusta* of Dailey (1973).

### Stratigraphic range in the Sundays River Formation

Restricted to the latest Early and earlier Late Hauterivian (late Biozone VIII to top Biozone VI), in more distal, middle to outer shelf localities: and one occurrence only in Biozone ?II.

*Dorothia australis* sp. nov.

Figs 36I–L, 38A–B

*Dorothia pupa* (non Reuss): McLachlan *et al.* 1976b: 352, fig. 11 (no. 5).*Marssonella kummi* (non Zedler): Kielbowicz *et al.* 1983: 321, pl. 1 (fig. 3, possibly fig. 2).*Diagnosis*

A *Dorothia* species characterized by up to four pairs of inflated, biserially arranged chambers in the later part of the slightly compressed, conical test, with weakly depressed, horizontally aligned sutures and convex septa. Test consists of an initial more conical portion and a later less rapidly widening part. Canaliculi present.

*Etymology*

From its occurrence in the Southern Hemisphere, in the austral province.

*Material*

*Holotype* (Fig. 36K). SAM–MF1222, SOEKOR negative F574.

*Paratypes* (Figs 36I, J, L, 38A–B). MF1220, MF1221, MF1223 to MF1225, five specimens, SOEKOR negatives F634, F560, F586, F584, and F606.

*Stratum typicum*

Early Hauterivian Biozone X of the Sundays River Formation.

*Locus typicus*

MV 1/79, cuttings sample at 90 m.

*Description*

Test generally conical, with maximum width and depth at the level of the last-formed pair of chambers. Test periphery lobate in the later part of the test, weakly arched in the initial part; very broadly rounded, subcircular in cross-section. Test slightly compressed, so that final portion is usually distinctly wider than deep. Initial part of test conical and increasing rapidly in width: composed of chambers arranged in a trochospire of two or three whorls, apparently with about four chambers in each whorl. Later part of test less rapidly widening, but still conical; composed of three, occasionally four pairs of biserially arranged chambers, increasing rather slowly and steadily in size as added; inflated, especially at the test periphery but less so close to the zigzag suture, so that in fully adult tests this suture lies in a depression. Terminal faces of final pair of chambers broad, gently arched, inflated. Sutures initially indistinct, flush, becoming distinct in the biserial part of the test, lightly depressed, straight, and aligned about horizontally to the test periphery. Aperture interio-marginal, an elongate slit in a recession at the base of the final chamber, so that the interio-marginal suture constitutes a distinct, gently sinuous curve over the terminal face. Apical point of test broad and rounded. Test surface faintly roughened, with wall composed of numerous small angular quartz grains set in abundant cement, leading

to an unusually smooth-walled agglutinated test when compared with other Sundays River Formation species. Canaliculi present.

### Remarks

Earlier distinctions by McLachlan *et al.* (1976b) between '*Dorothia kummi* (Zedler)' and '*Dorothia pupa* (Reuss)' were based to some degree on damaged and undamaged tests, respectively. Subsequent offshore drilling in the Pletmos, Gamtoos and Algoa basins through the Valanginian and Early Hauterivian has shown that the species is widespread, and is also subject to some variation as a consequence of post-depositional compaction. Tests from the Sundays River Formation are generally little affected by compaction, although the specimen in Figure 36J is certainly distorted. Offshore, tests akin to that of Figure 36K are commonest, and it is for this reason that this particular test has been chosen as holotype. It is also possible that some variation seen is due to dimorphism between the sexual and asexual generations, but this aspect remains to be followed up.

The '*Dorothia pupa*' of McLachlan *et al.* (1976b) is characterized by an unusually strongly inflated final chamber, but falls well within the morphological range accepted here for *Dorothia australis*. In contrast, the Mngazana and Brenton tests of '*Dorothia kummi*' (McLachlan *et al.* 1976a, 1976b) lack the inflated chambers, lobate periphery and inflated terminal face of *D. australis*, and would seem to be a different species, but it remains doubtful if they should be referred to Zedler's (1961) species. The Neuquén, Argentina, test of *Marssonella* sp. illustrated by Musacchio (1979) from the Late Hauterivian is clearly not referable here, but at least one of the two tests (pl. 1 (fig. 3)) figured by Kielbowicz *et al.* (1983) from the Valanginian of south Patagonia seems to be identical to *D. australis*.

All of the above tests referred to *D. australis* compare closely with the north-west European species *Marssonella kummi* Zedler, described from the later Hauterivian of northern Germany. Illustrations of *M. kummi* are given by Zedler (1961, pl. 7 (fig. 1a-c)), Ten Dam (1946, pl. 87 (fig. 9a-b)), Michael & Pape (1971, pl. 1 (fig. 3)), Bartenstein *et al.* (1971, pl. 1 (fig. 2)), Bartenstein & Brand (1951, pl. 4 (fig. 80a-b)), Bartenstein & Bettenstaedt (1962, pl. 35 (fig. 11a-b)), and Bartenstein & Kaeffer (1973, pl. 6 (fig. 105)). A possibly similar form, described as *Protomarssonella kummi* (Zedler), occurs in the Berriasian to Valanginian Barrow Group of ODP Site 762 off north-west Australia (Jones & Wonders 1992).

However, *Dorothia australis* differs from *Protomarssonella kummi* in lacking a nearly flat terminal face to the test (unless damaged), in possessing significantly more inflated later chambers and correspondingly more depressed sutures, a distinct vertically aligned depression superimposed over the zigzag suture, and in lacking the 'bullet-shaped' outline of *P. kummi*. The test of *P. kummi* figured by Guillaume & Sigal (1965) from the Late Hauterivian part of the Barremian stratotype section exhibits very much more inflated final chambers than is typical for the species. A comparison of the illustrated tests of *P. kummi* listed above, with those of *M. oxycona* (Reuss) and '*Dorothia*' *levis* Magniez-Jannin, figured by Magniez-Jannin (1975) is of value.



Although the Southern Hemisphere tests here referred to *D. australis* and the European *P. kummi* are morphologically close, there are distinct differences, and it seems best to consider the austral province occurrences as a separate genetic stock from those of the boreal province.

### Occurrence

*Dorothia australis* ranges through the Late Valanginian and earliest Hauterivian (Biozones C to X) of Pletmos Basin borehole PB-A1 (McLachlan *et al.* 1976b). In Argentina the species is known from the Valanginian Springhill Formation of southern Patagonia (Kielbowicz *et al.* 1983). The species occurs extensively in the Pletmos, Gamtoos and Algoa basins off the south coast of South Africa, where it appears in small numbers in the Late Berriasian, ranges through the Early Valanginian and becomes abundant in the Late Valanginian and earliest Hauterivian, before disappearing at the top of Biozone X.

### Stratigraphic range in the Sundays River Formation

Late Valanginian to early Early Hauterivian (Biozones C to top X). The species is ecologically sensitive, being absent from almost all marginal marine environments, and absent from areas of the sea-floor affected by sand or uninterrupted silt deposition. It is at its most frequent in the clayier Biozones Bb and Ba, above which it is rarer and rather erratically distributed.

### Supplementary note

It may be mentioned here that the Portlandian tests from the Colchester Member equivalent of borehole PB-A1 assigned the name *Dorothia subtrochus* (Bartenstein) by McLachlan *et al.* (1976b: 352, fig. 11 (no. 6)) should more properly be referred to either *Trochammina* or *Tritaxis*. This form has now been recognized elsewhere in the Portlandian, in the Bredasdorp-Infanta Basin off the south coast of South Africa. The species displays three or four chambers in later whorls. It may well be conspecific with the *Tritaxis*? aff. *Valvulina*? *fusca* (Williamson) of Musacchio (1979, pl. 1 (fig. 6)) from the Callovian of Neuquén, Argentina.

Genus *Gravellina* Brönnimann, 1953

*Gravellina* sp. A

Figs 38C-D

### Remarks

Seven tests referable to *Gravellina* occur in the Late Hauterivian (Biozones III to I) of AL 1/69 and adjacent distal boreholes. The tests are not well preserved, but they are very high-spined, quadriserial throughout, and display globular to subglobular chambers arranged in four vertical columns. They are reminiscent of a species of *Gravellina* typical of the earliest Barremian of Pletmos Basin, and the two occurrences may well be of the same species. In South Africa, *Gravellina* is confined to deep marine, slope environments low in oxygen and rich in organic debris.

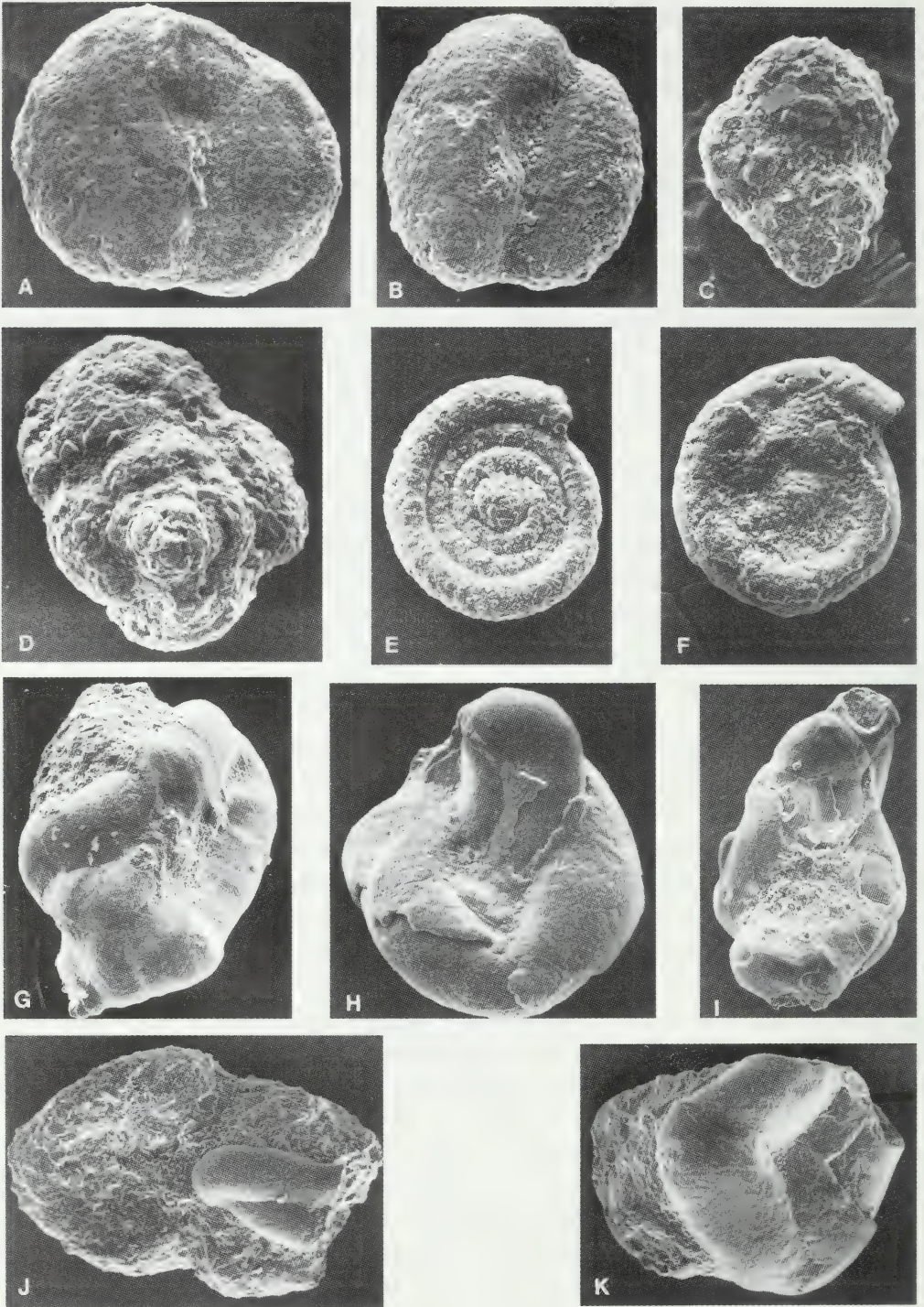


Figure 38.



Family **Textulariopsidae** Loeblich & Tappan 1982Genus *Plectinella* Marie 1956***Plectinella castlecliffensis*** sp. nov.

Figs 39A–F

*Diagnosis*

A small, slender, tapering *Plectinella* with inflated chambers, oblique sutures, a terminal, elongate-ovate aperture and an extremely fine-grained test wall.

*Etymology*

Named after the adjacent 'Castle Cliff' exposure of the Sundays River Formation in the Sundays River Valley.

*Material*

*Holotype* (Fig. 39A–B). MF1228.

*Paratypes* (Fig. 39C–F). MF1229, MF1230.

*Stratum typicum*

Exposure at first low-level bridge over the Sundays River just upstream from The Look Out, Biozone D, Late Valanginian, Sundays River Formation.

*Locus typicus*

Low-level bridge near The Look Out, SOEKOR sample 18589.

*Description*

Test elongate, slender, small, slightly compressed, with maximum width and depth at the lower part of the final pair of chambers. Test periphery lobate throughout; margin broadly rounded throughout. Chambers arranged biserially in up to four pairs and closely appressed. Chambers increase steadily in size as added and are generally a little higher than wide through the entire test. Later chambers are distinctly to strongly inflated. Sutures distinct, moderately to strongly depressed, oblique and declining to test periphery

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Fig. 38 (see facing page). A–B. *Dorothia australis* sp. nov. A. Paratype, SAM–PQ–MF1224, apertural view, MV 1/79, 140 m (X), F584.  $\times 212$ . B. Paratype, SAM–PQ–MF1225, apertural view, MV 1/79, 180–190 m (X), F606.  $\times 206$ . C–D. *Gravellina* sp. A. C. SAM–PQ–MF1226, ventral view, AL 1/69, 760 feet (II), F216.  $\times 171$ . D. SAM–PQ–MF1227, dorsal view, AL 1/69, 1 030 feet (III), F312.  $\times 187$ . E–F. *Cornuspira orbicula* (Terquem & Berthelin). E. SAM–PQ–MF1231, side view, AL 1/69, 640 feet (II), F199.  $\times 142$ . F. SAM–PQ–MF1232, side view, AL 1/69, 370 feet (I), F42.  $\times 151$ . G. ?*Calcitornella* sp., SAM–PQ–MF1233, test attached to *Ammobaculites*, AL 1/69, 670 feet (II), F208.  $\times 45$ . H–K. *Nubecularia lucifuga* Defrance. H. SAM–PQ–MF1234, test ?not attached, AL 1/69, 4 110 feet (A), F550.  $\times 172$ . I. SAM–PQ–MF1235, test attached to agglutinated foraminifera shell, AL 1/69, 1 540 feet (VI), F420.  $\times 75$ . J. SAM–PQ–MF1236, test attached to *Ammobaculites* sp., AL 1/69, 3 350 feet (IX), F534.  $\times 75$ . K. SAM–PQ–MF1237, test attached to *Ammobaculites* sp., AL 1/69, 2 190 feet (VIII), F494.  $\times 80$ .



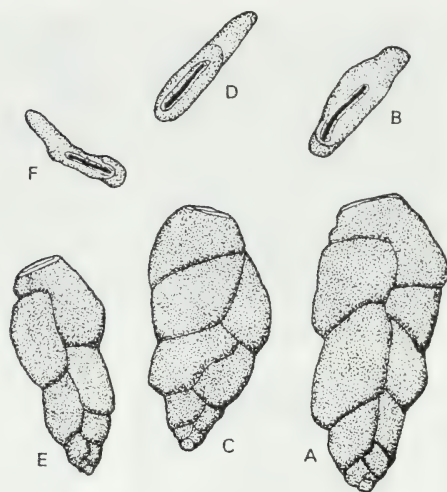


Figure 39.

*Plectinella castlecliffensis* sp. nov. A–B. Holotype, SAM–PQ–MF1228, side and apertural views, exposure at first low-level bridge just upstream from The Look Out, SOEKOR sample 18589 (D). x 128. C–D. Paratype, SAM–PQ–MF1229, side and apertural views, SOEKOR sample 18589 (D), x 171. E–F. Paratype, SAM–PQ–MF1230, side and apertural views, SOEKOR sample 18589 (D). x 233.

at an angle of about  $45^\circ$  to horizontal. The median suture forms a weakly depressed, gentle zigzag. Aperture terminal to sub-terminal, an elongate-ovate or sub-circular opening areally sited, with some occasional evidence of a faintly thickened lip around the opening. Apical end of test narrow, acute, and composed of a prominent, small, globular proloculus. Test wall extremely fine-grained, thin-walled, and composed exclusively of quartz grains.

#### Remarks

Loeblich & Tappan (1964) included Jurassic and Cretaceous biserial agglutinated forms with terminal apertures in the present-day genus *Pseudobolivina*. These included *Arenovirgulina aegyptiaca* of Said & Barakat (1958) and *Plectinella virgulinoides* of Marie (1956). More recently, the Jurassic and Cretaceous species have been separated from *Pseudobolivina* (see Banner & Pereira 1981; Loeblich & Tappan 1982, 1988) and are referred to *Plectinella*, of which *Arenovirgulina* is a junior synonym.

The examples from the basal Sundays River Formation are mostly distorted through compaction, although the 10 specimens utilized in the description given above provide a good indication of the undistorted test morphology. *Plectinella castlecliffensis* differs from Callovian *P. aegyptiaca* (Said & Barakat) in the more clearly inflated chambers, the obliquely oriented sutures, the more terminally sited and more nearly sub-circular aperture, and the absence of any twisting in the plane of addition of the biserial chambers. None of the Jurassic species of '*Pseudobolivina*' described by Souaya (1976) from Arctic Canada display inflated chambers in the style of *Plectinella castlecliffensis*. *Bimonilina variana* Eicher (1960), described from the Albion of Wyoming was

subsequently referred by authors to *Pseudobolivina*, following Loeblich & Tappan (1964). More recently, the genus *Bimonilina* has been re-instated (Loeblich & Tappan 1982, 1988). The aperture of *Bimonilina* is a thin, vertically aligned elongate slit rather than the sub-terminal, sub-circular opening of *Plectinella* and *Pseudobolivina*. It is not clear whether all references of '*Pseudobolivina variana* (Eicher)' from the Albian, Cenomanian and later Cretaceous rocks principally of North America are of true *Bimonilina*. *Plectinella castlecliffensis* appears to lack the inflated chambers of *Bimonilina reciprocata* Loeblich & Tappan (1982: 63, pl. 1 (figs 18–22)) from the Fort Worth Formation (Late Albian) of Texas. Because the Sundays River tests are clearly compressed, it is difficult to make an effective comparison between the elongate apertural openings of the two species.

#### *Stratigraphic range in the Sundays River Formation*

Confined to the basal Sundays River Formation, Late Valanginian Biozone D. The species has been encountered only in the Look Out area, northern Algoa Basin. It occurs only in association with marginally marine, possibly estuarine genera, such as *Miliammina*, where more normal marine genera such as *Haplophragmoides* are absent.

Family **Cornuspiridae** Schultze, 1854

Subfamily Cornuspirinae Schultze, 1854

Genus *Cornuspira* Schultze, 1854

*Cornuspira orbicula* (Terquem & Berthelin, 1875)

Figs 38E–F

*Spirillina orbicula* Terquem & Berthelin, 1875: 17, pl. 1 (fig. 12a–c).

*Cornuspira orbicula* (Terquem & Berthelin). Bartenstein & Brand, 1951: 279, pl. 4 (fig. 89a–c).

#### *Remarks*

Occasional specimens, mostly poorly preserved and always pyrite infilled, occur in the Late Hauterivian (Biozones II and I). These seem best referred to *Cornuspira orbicula*, described originally from the Middle Lias of France. The original description of the species indicates that the test surface is 'lisse, translucide', and no mention is made of test perforations that would indicate the species is a true *Spirillina*. Most later authors have considered the species to be porcellaneous in its wall construction, and their precedent is followed here.

Genus *Calcitornella* Cushman & Waters, 1928

?*Calcitornella* sp.

Fig. 38G

#### *Remarks*

Three porcellaneous-walled, attached specimens seem to be non-septate and referable to *Calcitornella*. However, it may be that they are referable to *Nubecularia lucifuga*



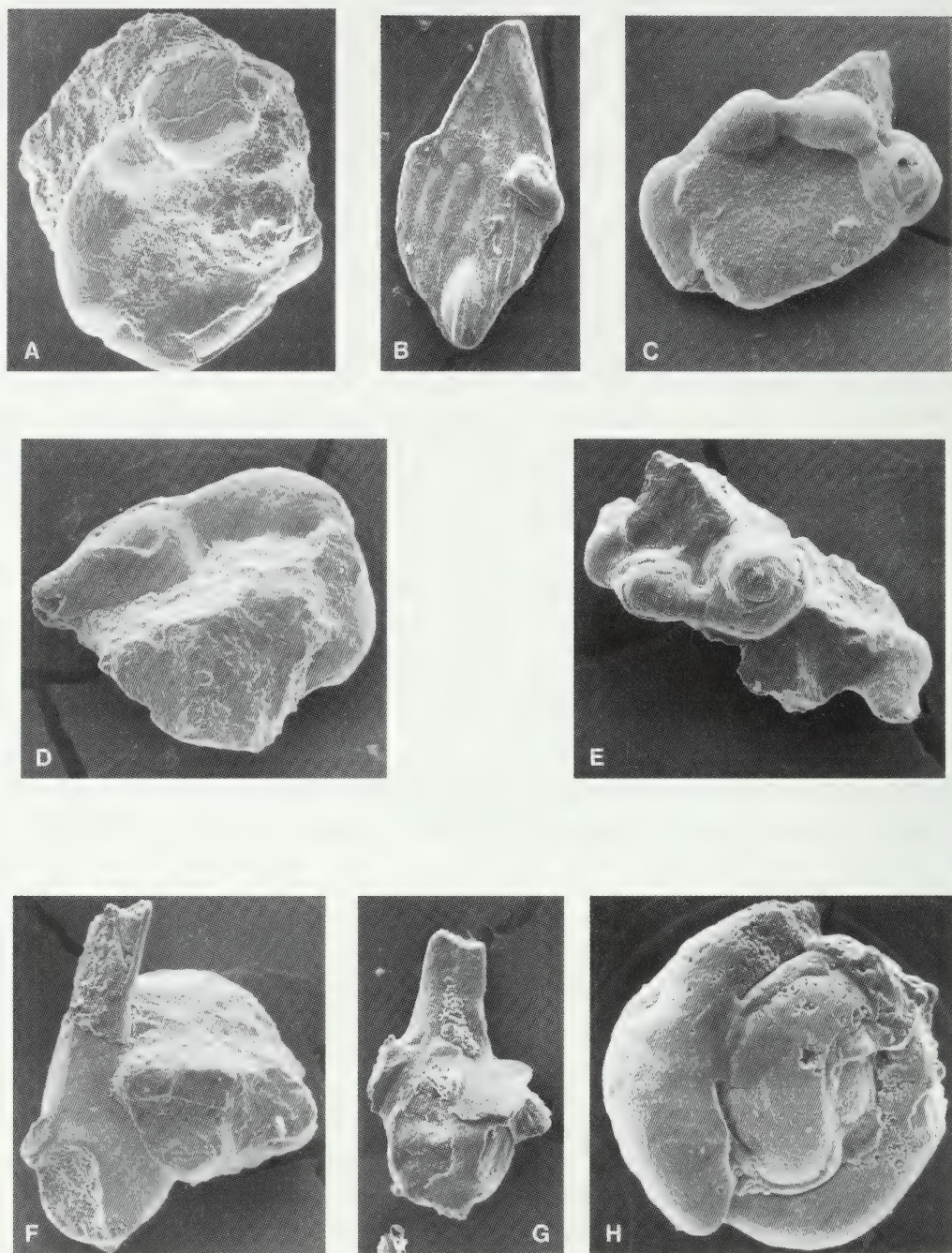


Figure 40.



Defrance (see below), with the chambers elongated and not at all inflated, so that the septal divisions are not evident in external view. The few specimens have somewhat precluded any attempts at thin sectioning. The illustrated ?*Calcitornella* test is attached to a fragment of an *Ammobaculites*, although it is not possible to determine which species. All ?*Calcitornella* sp. tests are from Biozone II of the Late Hauterivian, in the most distal borehole sections.

Family **Nubeculariidae** Jones, 1875

Genus *Nubecularia* Defrance, 1825

*Nubecularia lucifuga* Defrance, 1825

Figs 38H–K, 40A–B

*Nubecularia lucifuga* Defrance, 1825: 210, pl. 44 (fig. 3, 3a–d). Jones & Parker, 1860: 455, pl. 20 (figs 52–56). Arnold, 1967: 622, text-figs 1–12. McLachlan *et al.*, 1976a: 328.

### Remarks

In a detailed examination of Recent living specimens, and comparison between them and fossil material, Arnold (1967) has drawn attention to the confusion surrounding the taxonomy of *Nubecularia lucifuga* and its allied species. He concluded that 'in the light of (Arnold's) study of variability in natural and culture populations, careful examination of original descriptions of the thirty-odd species of living and fossil *Nubecularia* (and a not insignificant number of species assigned to other genera as well!) suggests quite strongly that almost half of them should more properly be assigned to *N. lucifuga*'. Following Arnold (1967), all *Nubecularia* specimens from the Sundays River Formation have been assigned to *N. lucifuga*.

This species was originally described from the Eocene of northern France (Defrance 1825), and has since been widely recorded, particularly from present-day, high-energy, highly oxygenated, shallow marine environments. The extant species is particularly common along those parts of the east coast littoral of South Africa that possess a rocky substrate. In contrast, all tests of *N. lucifuga* from the Sundays River Formation are from

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Fig. 40 (see facing page). A–B. *Nubecularia lucifuga* Defrance. A. SAM–PQ–MF1238, test attached to *Ammobaculites subaequalis* fragment, AL 1/69, 1 540 feet (VII), F422.  $\times 103$ . B. SAM–PQ–MF1239, test attached to *Fronicularia nieuwjaarskopensis*, shallow borehole SB–15, core 2, 210 feet (II), F677.  $\times 61$ . C–F. *Vinelloidea buchenroderi* sp. nov. C. Holotype, SAM–PQ–MF1240, attached to lithic grain, Uitenhage to Graaff-Reinet Road outcrop, sample 11464 (Bb), F62.  $\times 67$ . D. Paratype, SAM–PQ–MF1241, attached to lithic grain, Uitenhage to Graaff-Reinet Road outcrop sample 11464 (Bb), F63.  $\times 112$ . E. Paratype, SAM–PQ–MF1242, attached to lithic grain, Uitenhage to Graaff-Reinet Road outcrop sample 11464 (Bb), F64.  $\times 90$ . F. Paratype, SAM–PQ–MF1243, single chamber only attached to lithic grain, Uitenhage to Graaff-Reinet Road outcrop sample 11464 (Bb), F61.  $\times 105$ . G. *Nodobacularia* sp. A, SAM–PQ–MF1251, side view, single chamber only, Uitenhage to Graaff-Reinet Road outcrop sample 11464 (Bb), F71.  $\times 108$ . H. *Quinqueloculina* sp., SAM–PQ–MF1252, side view, AL 1/69, 1 240 feet (IV), F359.  $\times 215$ .

more distal, middle- and outer-shelf environments. A deeper marine milieu is perhaps also suggested by the specimen from the earliest Late Valanginian of the Mngazana Basin (McLachlan *et al.* 1976a). This difference either indicates a wider range of environmental preferences in the Mesozoic than in the Cainozoic, or that two different species or subspecies are being considered.

### *Occurrence*

Jones & Parker (1860; see also Adams 1962: 162) recognized the species in the Pliensbachian (Early Jurassic) of Chellaston, near Derby, England. Ten Dam (1950) described *N. trilocolina* from the Albion of the Netherlands, but Arnold (1967) obtained cultured individuals of *N. lucifuga* stock 'indistinguishable' from *N. trilocolina* tests. The species occurs in small numbers in the Portlandian Colchester Member of the Uitenhage Trough, onshore Algoa Basin (McMillan 1980), and in the Late Valanginian (Biozone B) in deeper waters (?) at Mngazana, Transkei (McLachlan *et al.* 1976a).

### *Stratigraphic range in the Sundays River Formation*

Very rare in the Late Valanginian Biozones Bb and Ba, and scattered occurrences, occasionally in some numbers in the Late Hauterivian (Biozones VII to I); absent elsewhere.

Genus *Vinelloidea* Canu, 1913  
***Vinelloidea buchenroderi* sp. nov.**  
Figs 40C–F

### *Diagnosis*

A species of *Vinelloidea* characterized by an attached test, composed of a globular proloculus, followed by a tubular, non-septate chamber of one whorl, and up to five inflated, pyriform chambers separated by distinct, abrupt septal necks, and with an irregular apertural opening at the termination of the test.

### *Etymology*

Named after Baron von Buchenroder, early palaeontology enthusiast in South Africa, who examined the eastern bank of the Swartkops River (Amsterdamhoek area) for fossils in 1828, with C. H. Grisbrook (1830). Von Buchenroder appears to have lived at the Swartkops River drift (Atherstone 1857: 532). The correct spelling of his name is unclear; Grisbrook's version is followed here.

### *Material*

*Holotype* (Fig. 40C). SAM–MF1240, SOEKOR negative F62.

*Paratypes* (Figs 40D–F). Three specimens, SOEKOR negatives F63, F64, and F61, SAM–MF1241 to MF1250, seven additional tests, all from sample 11464, Uitenhage to Graaff-Reinet Road outcrop.

*Locus typicus*

Sample 11464, Uitenhage to Graaff-Reinet Road cutting, located 1 km north of the basal Sundays River Formation, just east of Uitenhage town in the Uitenhage Trough.

*Stratum typicum*

Late Valanginian (basal Biozone Bb), Sundays River Formation.

*Description*

Test elongate, attached, meandering; test wall porcellaneous in construction. Test uniserial, composed of an initial, globular, rather prominent proloculus followed by a lower, tubular second chamber that encircles the proloculus for one whorl. Following the second chamber are from three to five inflated, pyriform chambers which taper anteriorly toward the following chamber. Sutures distinct, depressed; septal necks short and not severely constricted. Aperture terminal, sited at the end of the final chamber, apparently an irregular, subcircular and unornamented opening, although most tests studied are damaged around the aperture. Test wall smooth, unornamented. Most tests examined are coiled around lithic grains, and are never attached to fossil shell or other organic debris: in most cases they encircle grains of green or grey Palaeozoic slate rather than quartz grains. Some damaged specimens appear to have originally attached to more than one grain.

*Remarks*

Tests of *Vinelloidea buchenroderi* are confined to one sample (11464) from one of the road cuttings along the Uitenhage to Graaff-Reinet Road. They occur in association with other simple miliolids—a group that, in general, is rare in the Sundays River Formation. It seems likely that this assemblage reflects the proximity of wave-induced, highly turbulent and oxygen-rich conditions close to shore. This type of littoral appears to have been rather rare during the Late Valanginian and Hauterivian around the rim of the Algoa Basin, as hyposaline, estuarine conditions seem much more widespread.

Similar forms are known from the littoral and sub-littoral deposits occurring at Brenton (McLachlan *et al.* 1976b) in the Pletmos Basin, where they occur in some numbers. The Brenton simple miliolids were unfortunately not discussed by McLachlan *et al.* (1976b), but some of them do seem referable to *Vinelloidea buchenroderi*.

*Vinelloidea buchenroderi* can be distinguished from the type species, *V. crussolensis* Canu, 1913, synonymous with *Nubeculinella bigoti* Cushman (1930), described from the Oxfordian of northern France, by its more prominent proloculus and coiled second chamber, and its more regular, pyriform chambers in the later part of the test. *Vinelloidea buchenroderi* preferentially attaches to lithic grains, whereas *V. crussolensis* seems to select shell fragments (see Shipp & Murray 1981: 134, pl. 6.3.1 (fig. 17)).

*Stratigraphic range in the Sundays River Formation*

Apparently confined to the earliest part of Biozone Bb, Late Valanginian. However, since the distribution of *Vinelloidea buchenroderi* is obviously strongly facies controlled, this range is certainly artificial. Littoral and sub-littoral facies have been preferentially



removed during latest Hauterivian–earliest Barremian tilting and planation, and repeatedly thereafter, including during the series of regressive marine planations during the Pleistocene (upper Algoa Group times).

Genus *Nodobacularia* Rhumbler, 1895

*Nodobacularia* sp. A

Fig. 40G

#### Remarks

Nine separated chambers referable to *Nodobacularia* occur in sample 11464 from the road cutting 1 km north of the basal Sundays River Formation along the Uitenhage to Graaff-Reinet Road. The chambers are from free-living tests, possess very narrow septal necks (see illustrated specimen) and are ornamented with numbers of large, platy quartz grains. These fragments are morphologically similar to *Nodobacularia nodulosa* (Chapman), described from the Albian Gault Clay of England (Chapman 1891), but the test ornamentation is different.

#### Stratigraphic range in the Sundays River Formation

Lowest Biozone Bb, Late Valanginian, but see also the comments for *Vinelloidea buchenroderi* sp. nov. (p. 116).

Family **Miliolidae** Ehrenberg, 1839

Subfamily Quinqueloculininae Cushman, 1917

Genus *Quinqueloculina* d'Orbigny, 1826

*Quinqueloculina* spp.

Fig. 40H

#### Remarks

Six tests referable to *Quinqueloculina* have been obtained from the Sundays River Formation. All are badly preserved, but they are more nearly globular than is typical for *Q. minima* Tappan. These forms appear to have no distinctive stratigraphic range.

*Quinqueloculina minima* Tappan, 1943

Fig. 42A

*Quinqueloculina minima* Tappan, 1943: 490, pl. 78 (fig. 33a–b). Loeblich & Tappan, 1949: 255, pl. 48 (figs 12a–b, 13a–b). McLachlan *et al.*, 1976a: 328, fig. 16 (no. 2). Magniez-Jannin, 1984: 403, pl. 1 (fig. 22).

#### Remarks

Scattered tests in the Sundays River Formation appear best referred to *Quinqueloculina minima*. These shells are mostly poorly preserved. None possesses an apertural tooth, and all display a low, rather crescentic outline to the aperture.

*Occurrence*

Originally described from the Duck Creek Formation (Late Albian) of Oklahoma and Texas (Tappan 1943), and also known from the Albian Walnut Formation of Texas and Oklahoma (Loeblich & Tappan 1949). European records include the Aptian of Bulgaria (Iovcheva 1962), Barremian of Rumania (Neagu 1968), and Hauterivian–Early Barremian of France (Magniez-Jannin 1984). Present also in the Late Valanginian (Biozone B) of Mngazana Basin, Transkei (McLachlan *et al.* 1976a).

*Stratigraphic range in the Sundays River Formation*

Rare throughout, from Biozone A to Biozone I (Late Valanginian to Late Hauterivian).

Subfamily Rzehakininae Cushman, 1933

Genus *Miliammina* Heron-Allen & Earland, 1930

***Miliammina latrobei* sp. nov.**

Figs 41A–F

*Diagnosis*

A species of *Miliammina* distinguished by its small size, elongate-ovate outline, inflated, rounded chambers, broadly rounded test periphery and extremely fine-grained, rather glassy test wall.

*Etymology*

Named after Abbé Latrobe, who, while on an ecclesiastical tour through the eastern Cape in 1815, first reported the occurrence of fossils at the Addo Wagon Drift over the Sundays River (Latrobe 1818; Meiring 1959: 15).

*Material*

*Holotype* (Figs 41A–C). SAM–MF1254.

*Paratypes*. One specimen (Fig. 41D–F) and ten additional specimens from borehole CO 1/67, core sample at 3 311 feet, SAM–MF1255 to MF1264.

*Stratum typicum*

Earliest Late Valanginian (Biozone D), Sundays River Formation.

*Locus typicus*

Borehole CO 1/67, core sample at 3 311 feet.

*Description*

Test small, ovate to elongate-ovate in outline, inflated; maximum width usually at or near mid-height; periphery of test continuous, arched; in cross-section margin broadly rounded. Height of test about two-and-a-half times as wide. Chambers arranged in a quinqueloculine manner, increasing steadily in size as added, inflated. Chambers usually widest at their base, and narrowing to the foramen or aperture. Sutures distinct, depressed,

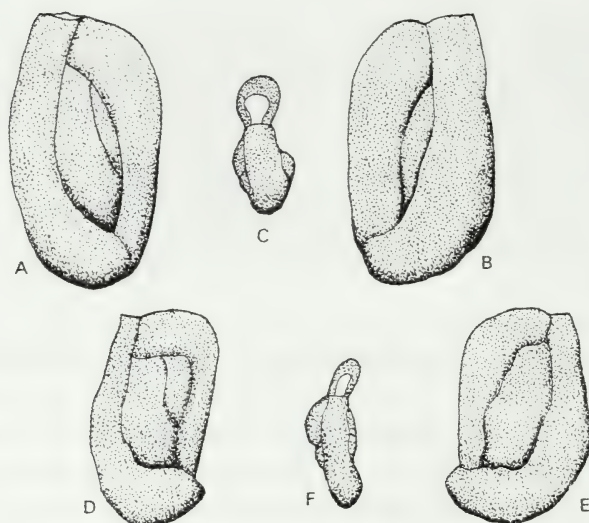


Figure 41.

*Miliammina latrobei* sp. nov. A–C. Holotype, SAM–PQ–MF1254, opposite side and apertural views, CO 1/67, 3 311 feet (D).  $\times 146$ . D–F. Paratype, SAM–PQ–MF1255, opposite side and apertural views, CO 1/67, 3 346 feet (D).  $\times 103$ .

usually curved but locally may be sinuous: this may be a natural feature or due to post-depositional test distortion. Aperture terminal, on the last-formed chamber, a sub-circular opening, apparently lacking any tooth structure. Surface of test smooth, almost glassy, greenish-olive in colour; test wall composed of abundant, very fine-grained quartz particles set in little cement: the grain size of the agglutinated material is very uniform.

### Remarks

*Miliammina latrobei* tests are mostly distorted and often flattened, due to post-depositional compaction. They are small in size when compared with the foraminifera shells from higher in the Sundays River Formation. This species is almost entirely restricted to core samples, and it is highly likely that it is much more extensively distributed through the basal Sundays River Formation than is seen in the samples studied.

Since the species is confined to hyposaline, possibly estuarine environments, its distribution through time may prove to be more extensive on the persistently hyposaline northern perimeter of the Sundays River Formation than further south, as in the latter region the 'estuarine' conditions associated with the marine transgression at the base of the sequence were of short duration and soon gave way to more normal marine environments. Unfortunately, available borehole data from the northernmost Algoa Basin do not confirm such a stratigraphic distribution.

*Miliammina latrobei* can be distinguished from *M. valdensis* Bartenstein & Brand (1951: 277, pl. 13 (figs 360a–c, 361a–b)) in its wider chambers revealing a clear taper from base to top, unlike the rather tubular chambers of the German species. The outline of



*M. latrobei* tests is elongate-ovate, often tending toward sub-rectangular, whereas *M. valdensis* is oval in outline. *Miliammina latrobei* is without the distinct apertural neck of *M. olgae* Bielecka (1960), and clearly differs from the narrow, elongate *M. jurassica* Haeusler (1882).

#### *Stratigraphic range in the Sundays River Formation*

Confined to hyposaline, ?estuarine environments in the earliest Late Valanginian (Biozone D). It may range higher in the northernmost, persistently marginal marine facies of the Sundays River Formation.

Family **Nodosariidae** Ehrenberg, 1838

Genus *Nodosaria* Lamarck, 1812 *s.l.*

The genus *Nodosaria* has been considered here in the broad sense. As detailed by Loeblich & Tappan (1988), various genera have been erected through the years that separate groupings of 'Nodosaria' on the basis of the test ornamentation, chamber morphology and aperture characteristics. Thus, it seems probable that *N. paupercula* Reuss should be more properly referred to the genus *Pyramidulina*, and perhaps also *N. obscura* Reuss and *Nodosaria* cf. *N. obscura* as understood herein. In contrast, *N. tomaszowiensis* Sztejn may be better referred to the genus *Nodomorphina*, although tests studied lack the compressed initial part, distinguished by a rectangular cross-section, and are without longitudinal costae at the test angles, since Sundays River tests are circular in section throughout.

*Nodosaria paupercula* Reuss, 1845

Figs 42B–K

*Nodosaria paupercula* Reuss, 1845: 26, pl. 12 (fig. 12). Neagu, 1965: 21, pl. 5 (fig. 18).

Magniez-Jannin, 1975: 197, pl. 12 (figs 35–36).

see *Nodosaria* (*Dentalina*) *paupercula* Reuss. Chapman, 1893: 593, pl. 9 (figs 13–14).

*Nodosaria* cf. *N. raristriata* (*non* Chapman): Espitalié & Sigal, 1963: 55, pl. 25 (figs 7–8).

#### *Remarks*

The Sundays River specimens appear to compare well with descriptions and illustrations of *Nodosaria paupercula* in Europe. However, these South African examples are distinctly older, being Valanginian and Hauterivian rather than Albian, and it may well be that more than one species is included under this name. Only detailed morphometric analysis is likely to distinguish different assemblages.

The tests from the Sundays River Formation show some variation in the degree of inflation of the chambers, the intensity of the ornamentation of vertically-aligned ribs, and in the degree to which the tests taper towards the proloculus. In all specimens, the ribs either fade away as they reach the short conical, terminal part of the final chamber, or they continue weakly and link with the teeth of the radiate aperture (Figs 42J–K). In the case of

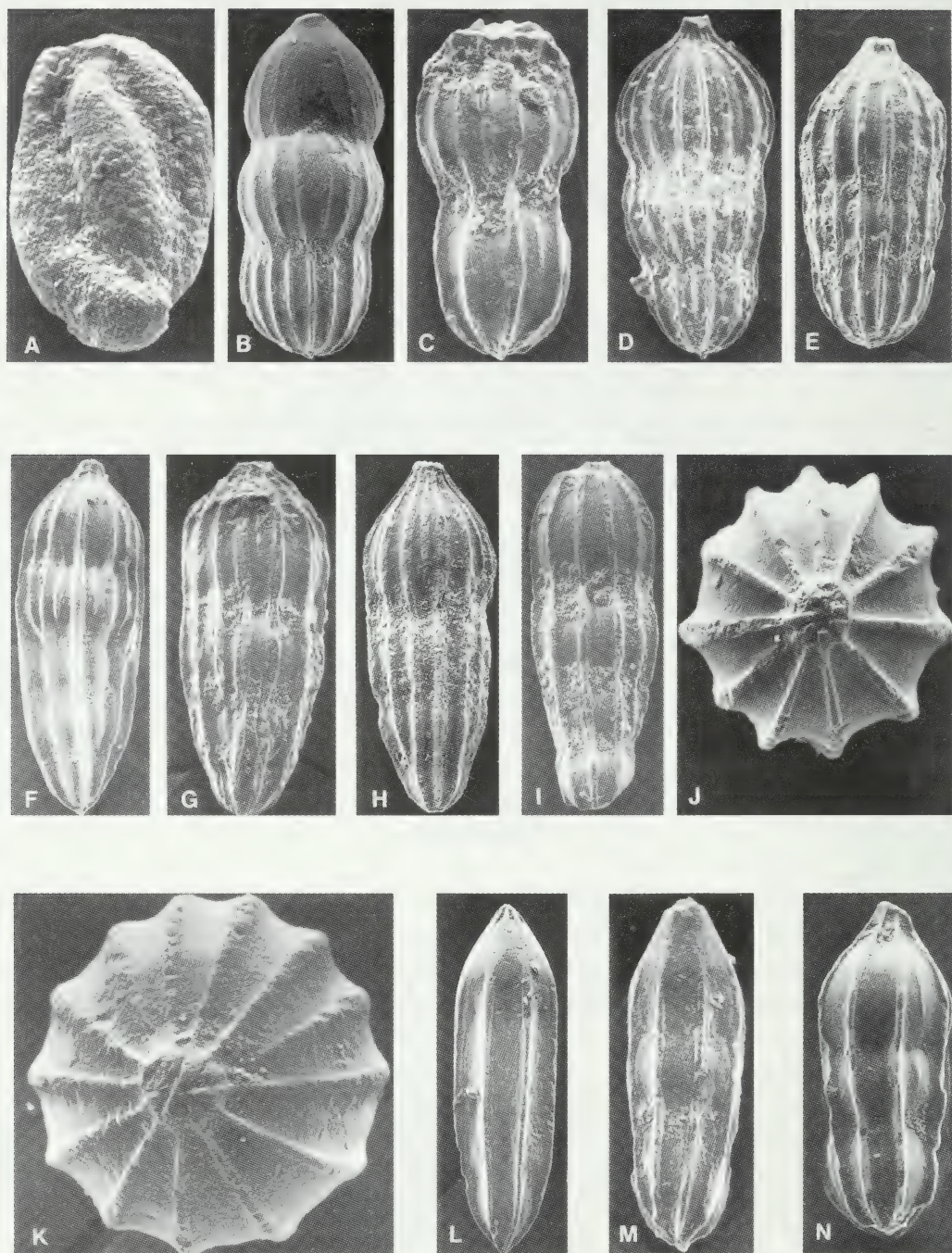


Figure 42.



the Albian tests from Europe, the ribs either fade away before reaching the base of the button-like apertural neck (Chapman 1893) or they continue and merge with it (Magniez-Jannin 1975, pl. 12 (fig. 36)). The specimen of *N. paupercula* illustrated by Tappan (1940, pl. 16 (fig. 11)) from the Middle Cenomanian Grayson Formation of Texas possesses a much more elongate test, with distinct septal necks between each chamber.

Espitalié & Sigal (1963) noted the presence of shells very similar to *N. paupercula* in Cenozoone F (Hauterivian to ?Barremian) in the Majunga Basin, Madagascar. The Sundays River Formation individuals compare particularly well with their form (Espitalié & Sigal 1963, pl. 25 (fig. 7). However, Espitalié & Sigal (1963: 55) erroneously compared their Majunga tests instead with the species *Nodosaria (Dentalina) raristriata* Chapman (1893), a long, very slender species described as being 'filiform', and clearly more typical of *Dentalina* s.l. than *Nodosaria* s.l.

### Occurrence

Described by Reuss (1845) from the Bohemian Cretaceous, and subsequently recorded from the Gault Clay (Albian) of Folkestone, England (Chapman 1893), the Albian of France (Magniez-Jannin 1975) and the Albian of Rumania (Neagu 1965). In the Southern Hemisphere it occurs in the Hauterivian to ?Barremian of Madagascar (Espitalié & Sigal 1963). *Nodosaria paupercula* has also been identified in the Hauterivian (Biozones IV to II) of Pletmos Basin borehole PB-A1 and in the earliest Late Valanginian (Biozone D) Brenton Formation, following a re-examination of the work presented by McLachlan *et al.* (1976b). Further offshore, in the Pletmos, Gamtoos and Algoa basins, *N. paupercula* ranges from mid-Early Valanginian to Early Barremian.

### Stratigraphic range in the Sundays River Formation

Occurs in small numbers throughout most of the sequence, from Late Valanginian Biozone Bb to Late Hauterivian Biozone I, although Early Hauterivian occurrences are few.

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Fig. 42 (see facing page). A. *Quinqueloculina minima* Tappan. SAM-PQ-MF1253, side view, MV1/79, 240–250 m, (A), F624.  $\times 162$ . B–K. *Nodosaria paupercula* Reuss. B. SAM-PQ-MF1265, side view, AL 1/69, 1 000 feet (III), F287.  $\times 78$ . C. SAM-PQ-MF1266, side view, AL 1/69, 1 720 feet (VII), F454.  $\times 107$ . D. SAM-PQ-MF1267, side view, AL 1/69, 1 270 feet (IV), F364.  $\times 57$ . E. SAM-PQ-MF1268, side view, AL 1/69, 370 feet, (I), F46.  $\times 68$ . F. SAM-PQ-MF1269, side view, AL 1/69, 460 feet (I), F103.  $\times 63$ . G. SAM-PQ-MF1270, side view, AL 1/69, 1 930 feet (VII), F465.  $\times 73$ . H. SAM-PQ-MF1271, side view, AL 1/69, 520 feet (I), F129.  $\times 70$ . I. SAM-PQ-MF1272, side view, AL 1/69, 1 630 feet (VII), F440.  $\times 72$ . J. SAM-PQ-MF1273, apertural view, AL 1/69, 580 feet (II), F169.  $\times 180$ . K. SAM-PQ-MF1274, apertural view, AL 1/69, 1 540 feet (VI), F419.  $\times 160$ . L–N. *Nodosaria obscura* Reuss. L. SAM-PQ-MF1275, side view, shallow borehole SB-28, core 1, 188 feet (VI), F689.  $\times 75$ . M. SAM-PQ-MF1276, side view, AL 1/69, 1 930 feet (VII), F466.  $\times 117$ . N. SAM-PQ-MF1277, side view, AL 1/69, 490 feet (I), F114.  $\times 140$ .



*Nodosaria obscura* Reuss, 1845

Figs 42L–N, 43A–B

*Nodosaria obscura* Reuss, 1845: 26, pl. 13 (figs 7–9). Bartenstein & Brand, 1951: 312, pl. 10 (figs 247–248). Malumián & Masiuk, 1975: 590, pl. 2 (fig. 8). Magniez-Jannin, 1975: 192, pl. 12 (figs 22–34), text-fig. 105. Malumián & Nañez, 1983: 376, pl. 1 (fig. 6).

*Nodosaria (Dentalina) obscura* Reuss. Chapman, 1893: 593, pl. 9 (fig. 16).

*Remarks*

Occasional *Nodosaria* tests are present in the Sundays River Formation that show variation in the degree of inflation of the chambers, the intensity, number and bladed or rounded nature of the vertically aligned ribs, and in the tapering or domed termination to the last-formed chamber. Tests generally possess from seven to ten ribs. The apical point of the test is usually acutely angled, but may also be slightly spinose on occasion. These tests compare well with the range of variation seen in assemblages of *N. obscura* from the French Albian (Magniez-Jannin 1975). Bartenstein (1954) and Magniez-Jannin (1975) have regarded *N. fontannesii* (Berthelin) as a junior synonym of *N. obscura*.

*Occurrence*

Widely reported in the Cretaceous, and described originally by Reuss (1845) from the Cretaceous of Bohemia. Later records include the Albian of Folkestone, England (Gault Clay) by Chapman (1893); the Albian of the Aube region, France (Magniez-Jannin 1975); Valanginian–Hauterivian Pampa Rincón Formation, Tierra del Fuego (Malumián & Masiuk 1975); and the Barremian Río Mayer Formation of Santa Cruz Province, Argentina (Malumián & Nañez 1983). The species is widespread but always rare in continental shelf sediments of Valanginian, Hauterivian and possibly Early Barremian age off the south coast of South Africa.

*Stratigraphic range in the Sundays River Formation*

Occasional specimens occur from Late Valanginian Biozone Bb to Late Hauterivian Biozone I.

*Nodosaria tomaszowiensis* Sztejn, 1957

Figs 43C–F

*Nodosaria tomaszowiensis* Sztejn, 1957: 53, 228, pl. 6 (fig. 48).

*Lenticulina (Nodosaria) aff. fontannesii* (non Berthelin): Damotte & Magniez-Jannin, 1973: 33, pl. 4 (fig. 11).

*Nodosaria sceptrum* (non Reuss): McLachlan *et al.* 1976a: 328, fig. 16 (no. 3).

*Nodosaria aff. fontannesii* (Berthelin) var. *flexocostata* [sic] (non Khan): Musacchio, 1979: 258, pl. 4 (fig. 5).

*Remarks*

With some uncertainty, a number of references to Early Cretaceous slender *Nodosaria* tests, ornamented with up to ten vertically aligned ribs are assigned to *N. tomaszowiensis*. These forms possess more ribs than is usual for *N. orthopleura* Reuss, which is characterized by five or seven. These tests are not as robustly built as those of *N. obscura* Reuss or *N. fontannesii* (Berthelin), and they appear to lack the stronger, more prominent ribs of *N. fontannesii* var. *flexocarinata* Khan (1950). If reference to *N. tomaszowiensis* proves to be inappropriate, it may be that this group warrants a new name.

*Occurrence*

Valanginian of Poland (Sztejn 1957), Aptian of France (Damotte & Magniez-Jannin 1973), Late Hauterivian of Neuquén (Musacchio 1979), as well as the Barremian Río Mayer Formation, Santa Cruz Province, Argentina (Malumián & Nañez 1983), and earlier Late Valanginian (Biozone B) of Mngazana Basin, Transkei (McLachlan *et al.* 1976a).

*Stratigraphic range in the Sundays River Formation*

Small numbers from Biozone Bb to Biozone II, generally at more distal localities.

*Nodosaria grisbrookii* sp. nov.

Figs 43G–J

*Diagnosis*

A species of *Nodosaria* distinguished by fine to moderately developed grooves vertically aligned on the test surface, mostly continuous but some infrequent, with the apical end of the test bluntly pointed, and a terminal, centrally sited, radiate aperture.

*Etymology*

Named after Mr C. H. Grisbrook, apothecarist of Graaff-Reinet and palaeontology enthusiast, who with Von Buchenroder, examined the fossils of the Amsterdamhoek outcrops in 1828 (Grisbrook 1830).

*Material*

*Holotype* (Fig. 43G). MF1284, SOEKOR negative F627.

*Paratypes* (Figs 43H–J). MF1285 to MF1287, three specimens, SOEKOR negatives F82, F79, and F599.

*Stratum typicum*

Late Valanginian Biozone A, Sundays River Formation.

*Locus typicus*

Borehole MV 1/79, cuttings sample 240–250 m.



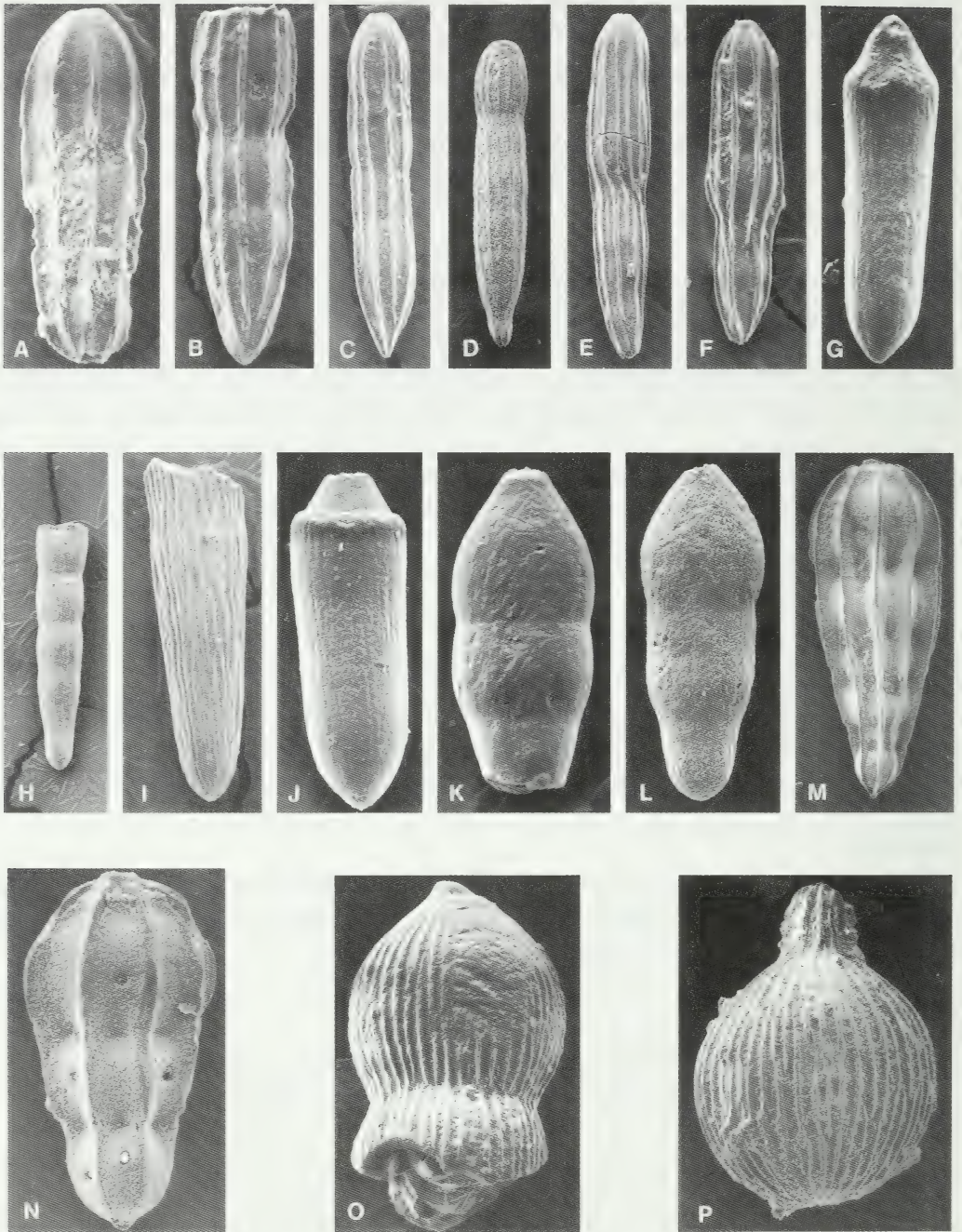


Figure 43.



### Description

Test elongate, almost cylindrical, slightly tapering, with maximum width of test at the level of the last-formed chamber. Test circular in cross-section. Chambers uniserially arranged throughout, rectilinear, never arched, with up to six chambers in most tests. Chambers increase very slowly and regularly in height as added, with later chambers a little wider than high. Sutures usually indistinct, becoming faintly evident and very lightly depressed between the final few chambers. All sutures are horizontal. Aperture terminal, a circular and radiate opening, centrally placed on the final chamber. Apical end of test bluntly pointed. Surface of test ornamented by fine, vertically aligned grooves, usually not too distinct, but occasionally more in evidence, in which case the intervening surfaces of the test have a rope-like appearance. Differences in the surface ornamentation may be due to diagenetic corrosion of tests. Test wall thick and robustly built.

### Remarks

The majority of tests found are the same as those illustrated in Figure 43G (holotype) and Figure 43J. It may well be that the specimen shown in Figure 43I displays the ornamentation closest to the original shell, when its occupant was alive, but clearly this cannot now be confirmed. The species possesses a distinctive surface ornamentation that is rather unlike previously described Early Cretaceous *Nodosaria* species.

The test referred to *Lingulina* sp. aff. *L. nodosaria* Reuss by Masiuk & Viña (1986a) from the Late Hauterivian of the Agrio Formation, southern Argentina, displays a fine ornamentation similar in intensity to that seen in *N. grisbrooki*. However, the Argentinian test is characterized by an elongate, slit-like aperture, and thus is clearly a *Lingulina*. Its slightly constricted sutures compare closely with those of the test illustrated here in Figure 43H.

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Fig. 43 (facing page). A–B. *Nodosaria obscura* Reuss. A. SAM–PQ–MF1278, side view, AL 1/69, 790 feet (III), F221.  $\times 147$ . B. SAM–PQ–MF1279, side view, AL 1/69, 1 480 feet (IV), F376.  $\times 126$ . C–F. *Nodosaria tomaszowiensis* Szejn. C. SAM–PQ–MF1280, side view, shallow borehole SB–15, core 4, 229 feet (II), F684.  $\times 93$ . D. SAM–PQ–MF1281, side view, Colchester Cliff outcrop sample 11444 (IV), F704.  $\times 150$ . E. SAM–PQ–MF1282, side view, Colchester Cliff outcrop sample 12001 (IV), F711.  $\times 61$ . F. SAM–PQ–MF1283, side view, shallow borehole SB–15, core 2, 210 feet (II), F675.  $\times 116$ . G–J. *Nodosaria grisbrooki* sp. nov. G. Holotype, SAM–PQ–MF1284, side view, MV 1/79, 240–250 m (A), F627.  $\times 113$ . H. Paratype, SAM–PQ–MF1285, side view, Uitenhage to Graaff-Reinet Road outcrop sample 11464 (Bb), F82.  $\times 35$ . I. Paratype, SAM–PQ–MF1286, side view, Uitenhage to Graaff-Reinet Road outcrop sample 11464 (Bb), F79.  $\times 99$ . J. Paratype, SAM–PQ–MF1287, side view, MV 1/79, 180–190 m (X), F599.  $\times 143$ . K–L. *Pseudonodosaria tenuis* (Bornemann). K. SAM–PQ–MF1290, side view, MV 1/79, 400–410 m (Ba), F647.  $\times 146$ . L. SAM–PQ–MF1291, side view, shallow borehole SB–29, core ?, 218 feet 6 inches (VI), F690.  $\times 81$ . M–N. *Nodosaria* cf. *N. obscura* Reuss. M. SAM–PQ–MF1288, side view, Zoetgeneugd Cliff outcrop sample 11450 (Bb), F232.  $\times 66$ . N. SAM–PQ–MF1289, side view, Zoetgeneugd Cliff outcrop sample 11450 (Bb), F233.  $\times 123$ . O–P. *Amphicoryna pletmosiana* sp. nov. O. Paratype, SAM–PQ–MF1293, side view of final chamber, neck broken off, AL 1/69, 790 feet (III), F219.  $\times 76$ . P. Paratype, SAM–PQ–MF1294, side view of proloculus with apertural neck, CO 1/67, 642 feet (VII), F139.  $\times 100$ .

*Stratigraphic range in the Sundays River Formation*

Present in small numbers from the Late Valanginian (Biozone Bb) to the Early Hauterivian (Biozone VIII). The species has also been found to occur in Pletmos Basin borehole PB-A1, in the highest Biozone C (at 1 500 feet) of the Late Valanginian, following revision of the work by McLachlan *et al.* (1976b).

*Nodosaria* cf. *N. obscura* Reuss, 1845

Figs 43M–N

see *Nodosaria obscura* Reuss, 1845: 26, pl. 13 (figs 7–9).

*Remarks*

Several tests of *Nodosaria* from sample 11450 (basal Biozone Bb, Late Valanginian) near the base of the Zoetgeneugd Cliff outcrop are clearly related to *N. obscura*, as discussed above, but reveal some distinct differences. These tests are substantially more tapered, possess up to nine bladed, vertically aligned ribs, with more inflated chambers and correspondingly more depressed sutures. In their test morphology they come close to *N. harrisi* Vieaux (see Magniez-Jannin 1975, pl. 12 (figs 38–42)), but they lack the delicately structured apertural neck of that species.

*Stratigraphic range in the Sundays River Formation*

Apparently confined to the earliest part of Biozone Bb in the Late Valanginian. This form may be restricted to shallow marine, well-oxygenated, normal marine environments.

Genus *Pseudonodosaria* Boomgaart, 1949

*Pseudonodosaria tenuis* (Bornemann, 1954)

Figs 43K–L

*Glandulina tenuis* Bornemann, 1854: 31, pl. 2 (fig. 3a–b).

*Pseudoglandulina tenuis* (Bornemann) Bartenstein & Brand, 1951: 315, pl. 13 (fig. 349). Szejn, 1957, 230, pl. 6 (fig. 53). Beer, 1970: 17, pl. 3 (fig. 3).

*Pseudonodosaria tenuis* (Bornemann) Winter, 1970: 35, pl. 4 (figs 127–128).

*Pseudonodosaria* sp. Butt, 1979: 259, pl. 1 (fig. 23).

*Remarks*

Few tests of a simple *Pseudonodosaria*, with weakly inflated chambers. The species is less sturdily constructed than *P. humilis* (Roemer). These tests compare closely with the specimen illustrated by Bartenstein & Brand (1951), but do not exhibit the distinctly inflated chambers of those figured by Winter (1970).

*Occurrence*

Described by Bornemann (1854) from the Lias of Göttingen, Germany, and later recorded from the latest Hauterivian of the Speeton Clay, north-east England (Fletcher

1973), the Middle and Late Valanginian of north-west Germany (Bartenstein & Brand 1951), the Portlandian (Bielecka & Pożaryski 1954) and Late Valanginian (Sztejn 1957) of Poland, the Early Kimmeridgian of southern Germany (Winter 1970) and the Barremian of DSDP Site 397 off Cape Bojador, north-west Africa (Butt 1979). There are also a number of references to the species in the Late Jurassic of Germany.

#### *Stratigraphic range in the Sundays River Formation*

Too few specimens occur to permit a precise statement on the range of *Pseudonodosaria tenuis*, but identified specimens occur in the Late Valanginian and Early Hauterivian (?Biozones Ba to VIII).

#### *Pseudonodosaria humilis* (Roemer, 1841)

Figs 60H–K

*Nodosaria humilis* Roemer, 1841: 95, pl. 15 (fig. 6).

*Pseudoglandulina humilis* (Roemer). Bartenstein & Brand, 1951: 315, pl. 10 (figs 266–271).

Bartenstein *et al.*, 1957: 37, pl. 7 (figs 153, 154, 155a–b).

*Pseudonodosaria humilis* (Roemer). Dailey, 1973: 66, pl. 9 (fig. 12). Magniez-Jannin, 1975: 198, text-fig. 106. Lott *et al.*, 1986: 44, fig. 51. Bertels, 1990: 274, pl. 6 (fig. 11).

*Pseudonodosaria* gr. *humilis* (Roemer). Malumián & Masiuk, 1975: 590, pl. 1 (fig. 7).

*Pseudoglandulina humilis* gr. (Roemer). McLachlan *et al.*, 1976a: 334, fig. 16 (no. 23).

#### *Remarks*

Magniez-Jannin (1975: 199) has pointed out that Reuss (1863), describing *Glandulina mutabilis*, remarked that the short and broad forms of his species were identical to *Nodosaria humilis* as described by Roemer (1841). Both Fuchs (1967) and Magniez-Jannin (1975) have concluded that these two species must be synonymous.

Examination of tests referred to *Pseudonodosaria humilis* from South Africa indicates that all are uniserial and rectilinear in their chamber arrangement, and none contain an initial polyserial portion typical of the Polymorphinacea. The species also occurs widely in the offshore Pletmos, Gamtoos and Algoa basins off South Africa, where it is particularly frequent in Early and Late Valanginian rocks (Biozones E to B). The extensive development of deep marine, anoxic or poorly oxygenated sea-floor environments in the latest Valanginian and Hauterivian (1At1 to 6At1) preclude its occurrence in rocks of that age in the distal Pletmos, Gamtoos and Algoa basins.

#### *Occurrence*

*Pseudonodosaria humilis* was originally described by Roemer (1841) from the Barremian of northern Germany. Other records include Albian (Magniez-Jannin 1975) and Aptian (Damotte & Magniez-Jannin 1973) of France; latest Valanginian to earliest Barremian (Fletcher 1973) and Valanginian to Hauterivian (Lott *et al.* 1986) of the Speeton Clay, north-east England; Hauterivian—Barremian to Aptian–Albian of California (Dailey 1973); Barremian (Bartenstein *et al.* 1957) and Aptian–Albian



(Bartenstein *et al.* 1966) of Trinidad; Cenozones A to F (Late Bathonian to ?Barremian) and older in the Majunga Basin, Madagascar (Espitalié & Sigal 1963); the Valanginian–Hauterivian Pampa Rincón Formation (Malumián & Masiuk 1975) of Tierra del Fuego, the Valanginian Springhill Formation of southern Patagonia (Kielbowicz *et al.* 1983) and the Hauterivian lower Río Mayer Formation (Bertels 1990), Argentina; and the Late Valanginian (Biozone B) of the Mngazana Basin, Transkei (McLachlan *et al.* 1976a).

#### *Stratigraphic range in the Sundays River Formation*

Present very rarely in the Late Valanginian (Biozones Bb and Ba) and the Early Hauterivian, but relatively frequently in the Late Hauterivian (Biozones VII to I). In contrast to its extensive occurrence in Late Valanginian rocks off the south coast of South Africa the species is scarce during this time period probably because of the lowered oxygen conditions on the sea-floor in the Sundays River Trough. The species is not typical of marginal marine conditions of any type, and is at its most abundant on the middle and outer shelf.

Genus *Amphicoryna* Schlumberger, 1881

*Amphicoryna pletmosiana* sp. nov.

Figs 43O–P, 44A–C

*Dentalina* cf. *multicostata* Beer, 1970: 10, pl. 1 (fig. 8) (*non* d'Orbigny).

?*Amphicoryna* sp. McLachlan *et al.* 1976b: 352, fig. 11 (no. 7).

#### *Diagnosis*

An *Amphicoryna* species with numerous fine vertical ribs ornamenting the exterior, some of which extend up the rather short and sturdy apertural neck, and with inflated, globular chambers.

#### *Etymology*

Named after its first published occurrence in the borehole PB–A1, drilled in 1970 on the northern margin of the Pletmos Basin.

#### *Material*

*Holotype*. MF1292, SOEKOR negative F1054, see McLachlan *et al.* (1976b, fig. 11 (no. 7)).

*Paratypes* (Figs 43O–P, 44A–C). MF1293 to MF1297, five specimens, SOEKOR negatives F219, F139, F375, F220, and F487.

#### *Stratum typicum*

Late Hauterivian, Biozone III, Pletmos Basin.

#### *Locus typicus*

Borehole PB–A1, cuttings sample at 930 feet.

### Description

Test elongate, uniserial, rectilinear or very faintly arcuate, with slow rate of increase in chamber size. Maximum width of test generally at mid-height of final chamber. Test composed of three or four chambers, globular in shape, and overlapping previous ones to a small degree. Sutures strongly marked, indented, and horizontal. Aperture apparently circular, developed at the termination of a rather short and wide neck. In none of the specimens studied is the aperture well preserved, and the neck is somewhat irregularly terminated. Surface ornamentation composed of numerous vertically aligned ribs, from thirty to fifty in number. Ribs in well-preserved examples sharply defined, narrow, with rounded peaks, and never bladed; in corroded specimens the ribs are more broadly rounded. The majority of the ribs are continuous over sutures, although a little subdued. Occasional ribs extend for less than one chamber. At the apical end of the test, the ribs fade to a fairly smooth and unornamented area. About sixteen or twenty of the ribs continue from the last-formed chamber and range up the apertural neck to its termination. Test wall thick, robust.

### Remarks

No complete tests of this species have yet been encountered in either the Pletmos or Algoa basins. The majority of specimens consist only of detached single chambers, and all Sundays River Formation examples found so far are in this state, with the slight exception of the specimen illustrated as Fig. 43O. However, enough fragments exist to establish the nature of the species. *Amphicoryna pletmosiana* is a very distinctive species, even when fragmented tests are predominant, and its occurrence is the basis of an easily recognizable biozone. Beer (1970) first illustrated this species, using the name *Dentalina* cf. *multicostata* d'Orbigny, from the Late Hauterivian of borehole CO 1/67.

The genus *Amphicoryna* is best known from the Neogene and the Quaternary, and one extant species, *A. scalaris* (Batsch), is widely known around South Africa. However, earlier records of the genus are very sparse, and an Early Cretaceous occurrence of the genus seems unusual. The apertural neck, in its height and width, is not comparable to the delicate necks seen on later Cainozoic examples of the genus. Even so, this species is clearly distinct from all other *Nodosaria* species known in the South African Valanginian, Hauterivian and Barremian by its apertural neck and constricted sutures, and it therefore clearly merits separation from them into another genus. No similar species have been found in available literature.

### Stratigraphic range in the Sundays River Formation

Ranges from Biozone VII to the top of Biozone III in the Late Hauterivian. The species is typical of middle- and outer-shelf environments, both in the Algoa and the Pletmos basins. It would seem to be able to survive on relatively sandy substrates, as tests are common in silty sandstone core samples from borehole CO 1/67.



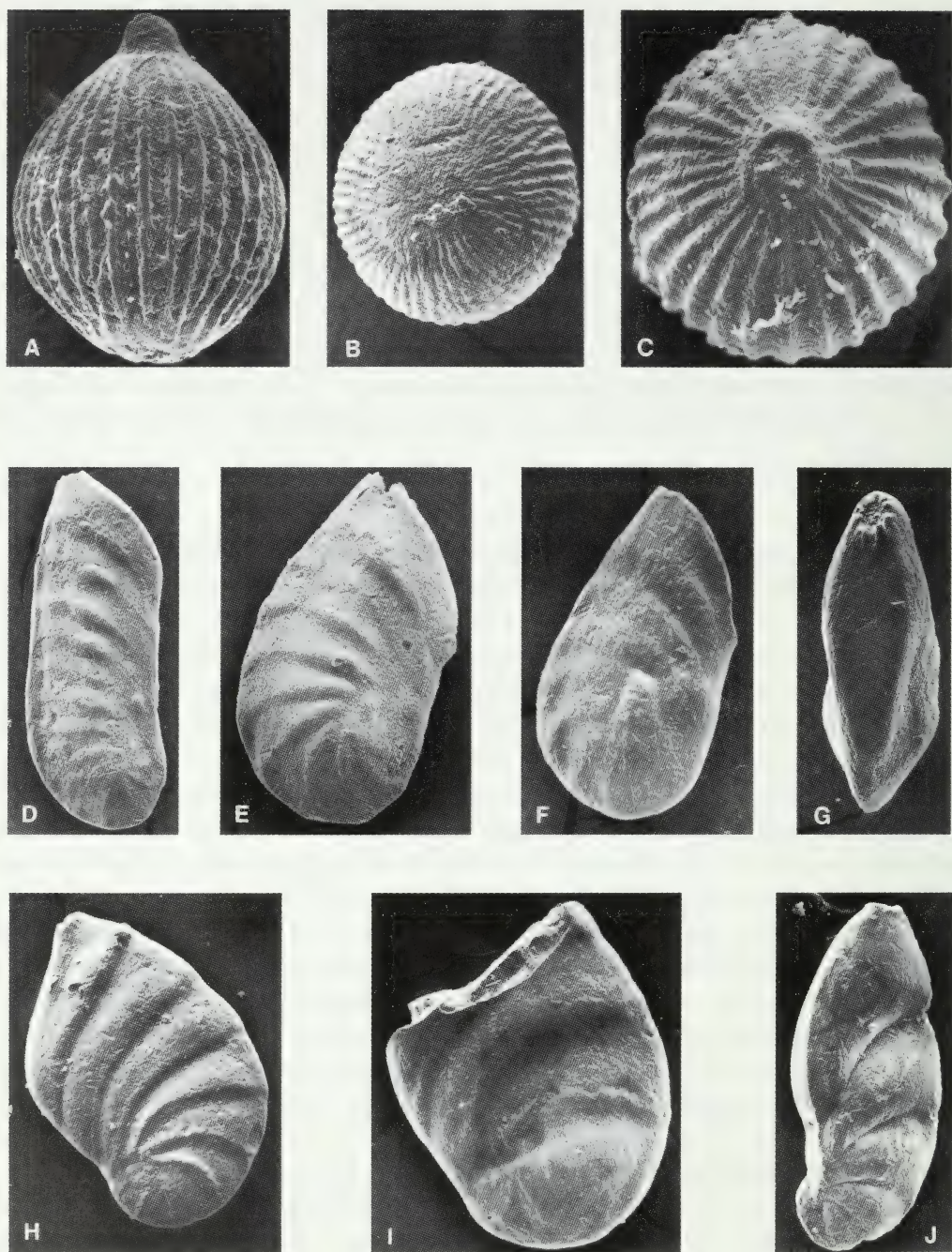


Figure 44.



Genus *Astacolus* de Montfort, 1808 *s.l.**Remarks*

The genus *Astacolus* is here considered in the wide sense. *Astacolus calliopsis* (Reuss) *s.l.*, *A. schloenbachi* (Reuss), and *Astacolus* sp. C in particular, as understood herein, may be better referred to the genus *Hemirobulina* (see Loeblich & Tappan 1988).

*Astacolus gilli* sp. nov.

Figs 44D–G

*Diagnosis*

A species of *Astacolus* characterized by an elongate, mostly parallel-sided test, elongate-lenticular in cross-section, with acutely rounded test peripheries, and maximum width and depth of test at about proloculus level.

*Etymology*

Named after Dr Gill, who collected fossils from the banks of the 'Zondag River', probably at Zoetgeneugd Cliff, prior to 1830 (Grisbrook 1830).

*Material*

*Holotype* (Fig. 44D). MF1298, SOEKOR negative F252.

*Paratypes* (Figs 44E–G). Three specimens, SOEKOR negatives F65, F491, and F251, and five additional specimens from different depths in borehole MV 1/79; from MF1299 to MF1301, MF1639 to MF1643.

*Locus typicus*

Sample no. 11452, basal part of Zoetgeneugd Cliff outcrop.

*Stratum typicum*

Late Valanginian Biozone C of the Sundays River Formation, onshore Algoa Basin.

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Fig. 44 (*see facing page*). A–C. *Amphicoryna pletmosiana* McMillan sp. nov. A. Paratype, SAM–PQ–MF1295, side view of final chamber with ?damaged neck, AL 1/69, 1 420 feet (IV), F375.  $\times 116$ . B. Paratype, SAM–PQ–MF1296, apical view, AL 1/69, 790 feet (III), F220.  $\times 88$ . C. Paratype, SAM–PQ–MF1297, apertural view, neck broken off, AL 1/69, 2 020 feet (VII), F487.  $\times 143$ . D–G. *Astacolus gilli* sp. nov. D. Holotype, SAM–PQ–MF1298, side view, Zoetgeneugd Cliff outcrop sample 11452 (C), F252.  $\times 38$ . E. Paratype, SAM–PQ–MF1299, side view, Uitenhage to Graaff-Reinet Road outcrop sample 11464 (Bb), F65.  $\times 50$ . F. Paratype, SAM–PQ–MF1300, side view, AL 1/69, 2 110 feet (VIII), F491.  $\times 67$ . G. Paratype, SAM–PQ–MF1301, apertural view, Zoetgeneugd Cliff outcrop sample 11452 (C), F251.  $\times 98$ . H–I. *Astacolus humilis* (Reuss). H. SAM–PQ–MF1302, side view, AL 1/69, 1 660 feet (VII), F445.  $\times 39$ . I. SAM–PQ–MF1303, side view, AL 1/69, 1 780 feet (VII), F450.  $\times 59$ . J. *Astacolus* sp. C, SAM–PQ–MF1304, side view, MV 1/79, 170 m (X), F598.  $\times 98$ .

### Description

Test strongly compressed, with maximum width and depth at or near the level of the proloculus. Test almost parallel-sided throughout, and elongate-lenticular in cross-section. Test composed of relatively small initial coil, composed of over one whorl of chambers, followed by uniserial uncoiled portion, the latter accounting for over three-quarters of the test in adult examples. Equatorial periphery of test acutely rounded throughout, never carinate or angled, although a thick flange with a rounded margin is often developed along the dorsal periphery in the early uncoiled portion of adult tests. Axial periphery initially subcircular around the coil, becoming linear, never lobate on either ventral or dorsal margin, except occasionally at the level of the last formed chamber. The coiled portion of the test exhibits about six visible chambers, with the uncoiled portion containing up to ten chambers. Chambers in final part of test about five times as wide as high. Sutures generally distinct; in initial part of test raised, limbate and regularly curved; in uncoiled part they are strongly limbate and raised centrally, but weakly raised to flush near to both the ventral and dorsal margins. The sutures thus tend to be marked best along a central band by a series of elongate-ovate swellings. Sutures of uncoiled part are gently curved, initially horizontal, but attaining an angle of about forty-five degrees by the final chamber. Surface of test smooth, generally unornamented. Umbilical area raised, but not infilled by any form of boss. Aperture terminal, located at the dorsal margin, in form a radial opening. Terminal face of last-formed chamber smooth, flat or weakly depressed. Test wall rather thick.

### Remarks

*Astacolus gilli* is rather more compressed than is typical for the genus, and given the uncertain boundaries of many of the nodosarid genera, could with some justification be regarded as a species of *Vaginulinopsis*. However, the size of the initial coil is perhaps sufficient to regard it as an *Astacolus*.

*Astacolus gilli* can be distinguished from *A. mutilatus* Espitalié & Sigal (1963) by its fewer (six rather than twelve) chambers in the final whorl of the coiled part of the test, in the lack of a sub-carinate margin, the lack of such an acutely triangular terminal face, even in juvenile specimens, and in its distinctly less positive sutures. *Astacolus gilli* differs markedly too from *Astacolus/Marginulina humilis* (Reuss): the chamber arrangement, and more especially the height to width ratio of the last-formed chambers of *A. gilli* bears little comparison with the tests illustrated by Reuss (1863, pl. 6 (figs 16a–b, 17a–b)) or Damotte & Magniez-Jannin (1973, pl. 3 (figs 32–39)).

Some confusion also existed initially between this species and *Astacolus* sp. A of McLachlan *et al.* (1976b: 353, fig. 12 (nos 1–4)). It is now clear that *Astacolus* sp. A consists of two distinct forms, one of Portlandian and one of early Late Valanginian age. *Astacolus gilli* can be distinguished from both by consistent differences in the outline of the test, the nature of the sutures and the degree of carination of the test periphery. Some of the Brenton Formation samples studied by McLachlan *et al.* (1976b) contain very large numbers of the early Late Valanginian (Biozone D) form of *Astacolus* sp. A (McLachlan *et al.* 1976b, fig. 12 (nos 1, 3)). Many of these are perfectly preserved, and adult examples

show that the final uncoiled chambers always diminish significantly in size. The sutures of the Brenton form remain raised and limbate across the entire width of the test, and through most of the test, but they become depressed between the final few chambers. The dorsal periphery is ornamented with a wide, bladed keel. The limbate sutures of the coiled part of the test converge over the umbilicus to form a distinct nodular swelling. None of these features are seen in *Astacolus gilli*.

The Portlandian *Astacolus* sp. A (McLachlan *et al.* 1976b, fig. 12 (nos 2, 4)), from the Colchester Member equivalent of borehole PB-A1, is distinct from *A. gilli* in its weakly limbate and less raised sutures, which are uniformly ornamented along their entire length, the absence of a parallel-sided uncoiled part of the test and, most noticeable of all, in the presence of a large, domed, glassy boss over the umbilicus. No similar forms to *A. gilli* have been described or illustrated to date from localities in South America or in Madagascar.

#### *Stratigraphic range in the Sundays River Formation*

*Astacolus gilli* is confined to the highest Biozone C, Biozones Bb and Ba (Late Valanginian) in the onshore Algoa Basin. One specimen only has been found in Biozone VIII, Early Hauterivian (Fig. 44F). It appears to have tolerated quite a range of environments, from sub-littoral to outer shelf, but is absent in hyposaline facies along the northern margins of the Sundays River Formation. The species is also known from the Late Valanginian Biozones D to B of borehole PB-A1, and in rocks of the same age the species is scattered throughout the offshore Pletmos Basin, and locally in the offshore Gamtoos and Algoa basins.

#### *Astacolus humilis* (Reuss, 1863)

Figs 44H-I

*Cristellaria humilis* Reuss, 1863: 65, pl. 6 (figs 16a-b, 17a-b).

see *Lenticulina* (*Astacolus*) *pachynota* (non Ten Dam): Zedler, 1961: 37, pl. 8 (fig. 7a-c).

*Lenticulina*/*Marginulina*/*humilis* (Reuss). Damotte & Magniez-Jannin, 1973: 28, pl. 3 (figs 32-39).

*Astacolus neopachynota* (non Bartenstein & Kaeffer): McLachlan *et al.*, 1976b: 353, fig. 11 (nos 28-29).

#### *Remarks*

There appears to be considerable variation in interpretation of *Astacolus neopachynota*, especially in the width of the uncoiled part of the test. Ten Dam (1946) illustrated *Vaginulinopsis pachynota*, which possesses a fairly compressed test, with limbate, elevated and almost ribbed sutures, especially in the median portion of the test, away from both ventral and dorsal margins. In contrast, the shells illustrated by Bartenstein & Kaeffer (1973), upon renaming the species, are not quite as wide, and the sutures of the median part of the test appear to be depressed rather than raised. The example figured by Zedler (1961) is much closer in its morphology to the original specimens illustrated by Ten Dam (1946).



In South Africa, tests referable to either *A. neopachynota* or *A. humilis* occur only very rarely, both in Pletmos Basin and the onshore Algoa Basin. They are wider and more strongly compressed, almost flat-sided, than is typical for European *A. neopachynota*. Consequently, the South African tests have been referred to *A. humilis*, but even here, some differences can be seen. In particular, there are variations in the intensity of limbation and degree of elevation of the sutural ornament both between Reuss's two figured tests, and within the South African tests.

#### Occurrence

Described from the Upper Hils Clays (?Barremian) of northern Germany (Reuss 1863); Aptian of the Aube district, France (Damotte & Magniez-Jannin 1973); Biozone IX, Early Hauterivian, of borehole PB-A1, Pletmos Basin (McLachlan *et al.* 1976b).

#### Stratigraphic range in the Sundays River Formation

Biozone VII, Early Hauterivian, but so rare that it is probable there are too few specimens to confidently define its full range.

#### *Astacolus* sp. C

Fig. 44J

#### Remarks

Although possessing a flat ventral surface to the uncoiled portion of the test, reminiscent of species of *Pravoslavlevia* and *Saracenaria*, this ventral face is narrow, and the single specimen found thus seems best referable to *Astacolus*. The specimen is characterized by sharply incised sutures, especially in the uncoiled portion. A number of South African species of *Lenticulina* and *Astacolus*, particularly in the Early and Late Valanginian, possess various styles of deeply incised sutures. Most however also feature strong test surface ribbing patterns, and *Astacolus* sp. C is rather unique in being otherwise unornamented. The single specimen of *Astacolus* sp. C is from Biozone X, Early Hauterivian.

#### *Astacolus microdictyotos* Espitalié & Sigal, 1963 *s.l.*

Figs 45A–K

*Astacolus microdictyotos* Espitalié & Sigal, 1963: 33, pl. 10 (figs 6a–b, 7a–d). Cañon & Ernst, 1974: 73, pl. 1 (fig. 19a–c). McLachlan *et al.*, 1976b: 353, fig. 11 (nos 23–25). Kielbowicz *et al.* 1983: 322, pl. 1 (figs 5–9). Bertels, 1990: 255, pl. 2 (fig. 2). Malumián, 1990: 448, pl. 1 (fig. 1). *Cristellaria dictyodes* (non Deecke): Martínez & Ernst, 1965: 9.  
*Lenticulina* (*Astacolus*) *microdictyotos* (Espitalié & Sigal). Beer, 1970: 13, pl. 2 (fig. 9).  
*Astacolus microdictyotus* Espitalié & Sigal. Riegraf, 1989: 1055, pl. 2 (fig. 2).

#### Remarks

Espitalié & Sigal (1963) described the holotype of *Astacolus microdictyotos* from the Majunga Basin, Madagascar, as being characterized by a well-developed, initial coiled

portion of the test with about nine chambers in its final whorl, followed by only two uncoiled chambers. Such forms do not occur in the Late Jurassic and Early Cretaceous sediments of the southern offshore (Pletmos, Gamtoos, Algoa and Mngazana basins) of South Africa. All of the South African specimens available for study, from all four basins, contain no more than about three-quarters of a coil, composed of five or six chambers in the initial part of the test. The greater part of the test is uncoiled. The degree of sutural limbation and ornamentation is variable, but never exceeds that of the specimen illustrated by McLachlan *et al.* (1976b, fig. 11 (no. 23)). Despite these differences, the southern African tests are referred to *A. microdictyotos* because of the close similarity of ornamentation; for this reason the species is considered *sensu lato*.

Examination of ornamentation patterns and general test outline of *Astacolus microdictyotos* s.l. in the Sundays River Formation shows there to be two distinct groups of tests, which may warrant varietal status. The first, commoner group (see Fig. 45A–G) is characterized by a more intense surface ornamentation, with frequent elongate-ovate depressions aligned parallel to the direction of uncoiling of the test. As noted by Espitalié & Sigal (1963), the ornamentation decreases in intensity toward the apertural face of the final chamber, which itself is devoid of ornament (see Fig. 45F). In the Sundays River Formation, this group ranges throughout the Late Valanginian and Hauterivian; offshore the group ranges from the Berriasian up to the Early Aptian. The group is known from the Pletmos, Gamtoos, Algoa and Mngazana basins. In the case of the Mngazana Basin, *A. microdictyotos* s.l. of the first group was discovered during re-examination of the Mngazana foraminifera subsequent to the work presented by McLachlan *et al.* (1976a).

The second group, which is usually less common, is confined to the Late Valanginian and Early Hauterivian and older rocks of the Gamtoos and Algoa basins, and is distinguished by possessing a rather more compressed but wider test, with a finer, denser reticulated surface ornamentation. There is a tendency for the chambers to increase steadily in width, so that maximum width of the test is often at the level of the final chamber. The form illustrated by Kielbowicz *et al.* (1983, pl. 1 (fig. 8)) is clearly of this group. Sundays River Formation examples of this second group are illustrated in Figure 45H–K.

A third group of *Astacolus microdictyotos* s.l. is known particularly from the Portlandian of offshore borehole Hb-A1 in the southern Algoa Basin. This group contains tests that are very elongate, almost *Vaginulina*-like in their test morphology, with a fine reticulation pattern ornamenting the surface. The coarser patterning of most of the Sundays River Formation examples is lacking. The Majunga Basin tests, ranging from the Late Portlandian to the Late Valanginian, would seem to form a distinct fourth group, characterized by their large initial coil, small uncoiled portion and fine surface reticulation (Espitalié & Sigal 1963).

These four groups appear to have distinctly different stratigraphic ranges, and perhaps will prove to be of assistance in biostratigraphic correlation between southern South America, South Africa and Madagascar. It is possible that *Astacolus microdictyotos* s.l. has an ancestry in the European species *Lenticulina dictyodes* (Deecke), which is distinguished by a finely reticulate ornamentation closely comparable to the Southern



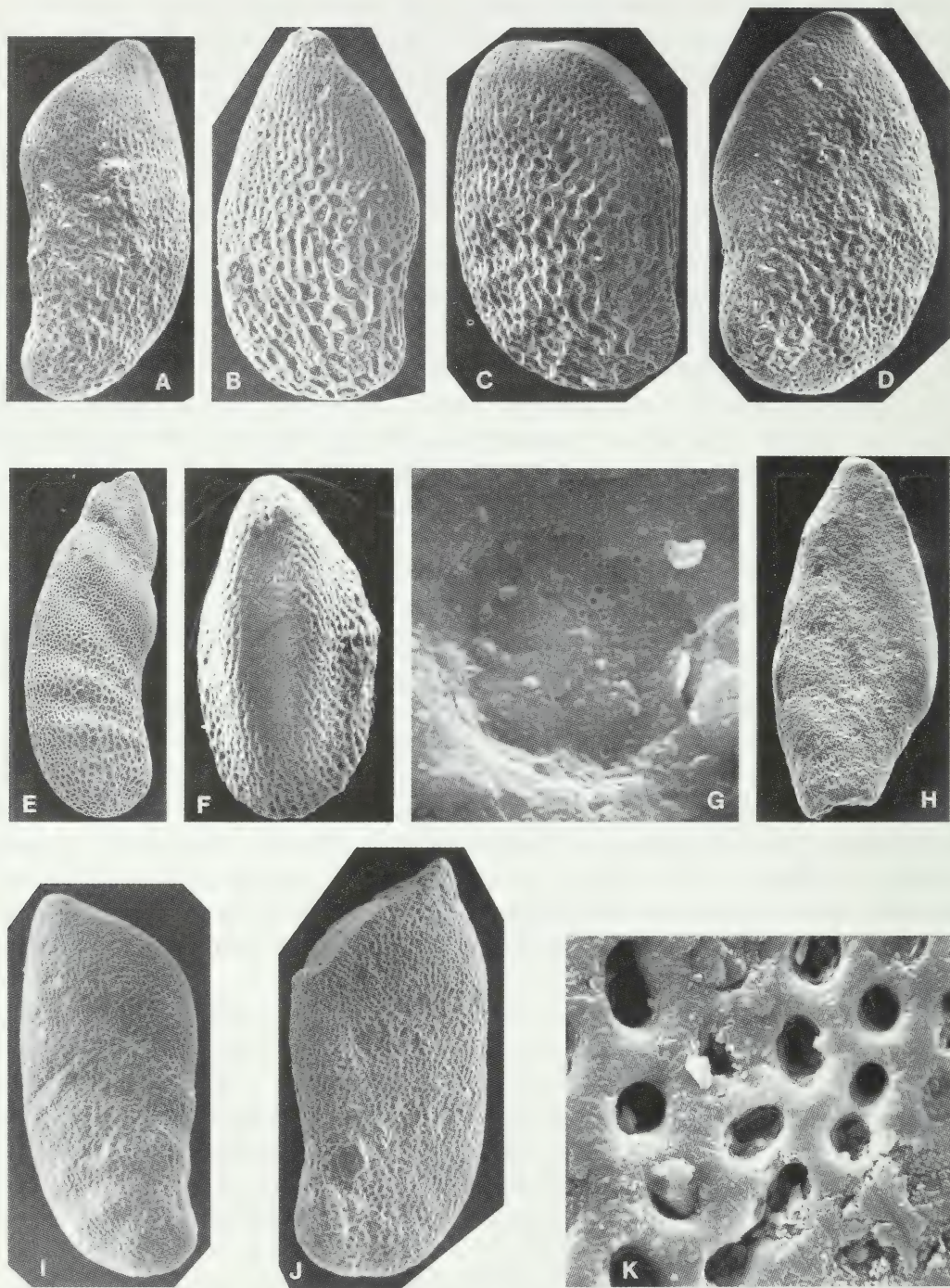


Figure 45.



Hemisphere species. *Lenticulina dictyodes* is typical of the Bajocian of north-west Germany (Bartenstein & Brand 1937: 178; Munk 1978, pl. 4 (figs 1, 3)) and the Bajocian to Bathonian of England (Coleman 1981: 118, pl. 6.2.3 (fig. 7); see also Morris & Coleman 1989, fig. 6.3.8 (fig. 7)). Despite being referred to *Lenticulina*, this European species is found with the final part of the test uncoiled, as figured by Coleman (1981), and thus may be considered an *Astacolus* as understood in the present work.

A further form, associated with *A. microdictyotos* s.l. by way of its surface ornamentation, is *Marginulinopsis pristipellis* Ludbrook (1966: 121, pl. 9 (fig. 6)), also illustrated by Scheibnerova (1976: 72, text-figs 73–74) from the Aptian of the Great Artesian Basin, Australia. *Marginulinopsis pristipellis* was formerly utilized as a down-hole marker to define the top Late Aptian of the southern offshore of South Africa, where it is confined to the continental shelf (McLachlan & McMillan 1979), but more recent work indicates it to range up to the top of the Middle Albian (McMillan *et al.* 1997). Its ornamentation pattern is very fine, the test is small, subcircular in cross-section, with an initial coil of about half a whorl and about four uncoiled rectilinear chambers in the later part of the test. For these reasons, South African *Marginulinopsis pristipellis* can clearly be distinguished from *A. microdictyotos* s.l., and the two are regarded as separate species. In contrast Malumián (1990) considered them synonymous. The final record of this style of ornamentation occurs extremely rarely in the Coniacian of the southern offshore of South Africa, where *Lenticulina*-like tests display a rather sparse reticulation. Attempts to correlate these into a lineage are probably not justifiable at present, and their origins may well be polyphyletic.

### Occurrence

Late Portlandian to Late Valanginian (Cenozoone D) in the Majunga Basin, Madagascar (Espitalié & Sigal 1963); Late Valanginian and Hauterivian of offshore borehole PB-A1, Pletmos Basin (McLachlan *et al.* 1976b) and Late Valanginian of the Mngazana Basin, Transkei (unpublished SOEKOR data), South Africa; Valanginian Springhill Formation of the Austral Basin, Patagonia (Kielbowicz *et al.* 1983; Malumián 1990); Springhill Formation and the *Favrella* beds of southern Chile (Martínez & Ernst 1965) and the ?Kimmeridgian–Oxfordian (Rinconian) to Barremian (Pratian) or Hauterivian (Esperanzian) of the Magallanes Basin, southern Chile (Natland *et al.* 1974—text-figure

Fig. 45 (see facing page). *Astacolus microdictyotos* Espitalié & Sigal s.l. A–G. Group 1. A. SAM–PQ–MF1305, side view, AL 1/69, 1 030 feet (III), F307.  $\times$  84. B. SAM–PQ–MF1306, side view, AL 1/69, 640 feet (II), F201.  $\times$  167. C. SAM–PQ–MF1307, side view, MV 1/79, 250–260 m (A), F629.  $\times$  142. D. SAM–PQ–MF1308, side view, MV 1/79, 240–250 m (A), F626.  $\times$  131. E. SAM–PQ–MF1309, side view, shallow borehole SB–32, core 1, 146 feet (IV), F692.  $\times$  64. F. SAM–PQ–MF1310, apertural view, MV 1/79, 250–260 m (A), F633.  $\times$  139. G. SAM–PQ–MF1311, close-up of ornamental pit, AL 1/69, 1 540 feet (VI), F411.  $\times$  1984. H–K. Group 2. H. SAM–PQ–MF1312, side view, MV 1/79, 160 m (X), F595.  $\times$  50. I. SAM–PQ–MF1313, side view, AL 1/69, 2 000 feet (VII), F481.  $\times$  85. J. SAM–PQ–MF1314, side view, AL 1/69, 3 660 feet (X), F541.  $\times$  96. K. SAM–PQ–MF1315, close-up of ornament, MV 1/79, 140 m (X), F582.  $\times$  1580.

discrepancies rather confuse the range in this work); there appear to be differences in age from the Chilean and Argentinian work on the Austral Basin. The full stratigraphic range of *A. microdictyotos* s.l. in South Africa is Early Portlandian to Early Aptian.

#### *Stratigraphic range in the Sundays River Formation*

Group 1 ranges from Biozone Bb to Biozone I, Late Valanginian to Hauterivian. Group 2 ranges from Biozone Bb to basal Biozone VII (Late Valanginian to earliest Late Hauterivian). The species is absent from shallow marine and hyposaline marginal marine facies, and is typical of middle and outer shelf locations.

#### *Astacolus gibber* Espitalié & Sigal, 1963

Figs 46A–H

*Astacolus gibber* Espitalié & Sigal, 1963: 36, pl. 13 (figs 8a–d, 9a–b, 10a–b, 11a–b). Malumián & Masiuk, 1975: 585, pl. 1 (figs 3, 4a–b). McLachlan *et al.*, 1976a: 328, fig. 16 (no. 5); 1976b: 352, fig. 11 (nos 10–12). Masiuk & Viña, 1986b: 60, pl. 1 (figs 1–5), pl. 2 (figs 2–7). Bertels, 1990: 253, pl. 1 (fig. 12).

*Lenticulina (Astacolus) gibber* (Espitalié & Sigal). Beer, 1970: 13, pl. 2 (fig. 8).

*Lenticulina reyesi* Cañon & Ernst, 1974: 74, pl. 2 (fig. 6a–b).

*Lenticulina (Astacolus) nodosa gibber* Espitalié & Sigal. Bartenstein, 1974: 550, pl. 2 (figs 7–8, 13–15). Aubert & Bartenstein, 1976: 16, pl. 2 (figs 1–8).

*Lenticulina nodosa* (non Reuss): Musacchio, 1979: 254, pl. 4 (fig. 8); 1981: 478, pl. 1 (fig. 1).

*Astacolus gibber gibber* Espitalié & Sigal. Malumián & Nañez, 1983: 382, pl. 2 (fig. ?7–8).

#### *Remarks*

A much clearer picture is now possible, resulting from numerous additional borehole sections and a more effective biostratigraphic correlation, of the exact relationships of *A. gibber* and *Lenticulina nodosa*, both in terms of their morphology and their stratigraphic range in South Africa. It has long been evident that *A. gibber* can be regarded as the fully adult form of *L. nodosa*, since it possesses the final, uncoiled portion of the test. Many specimens from the Sundays River Formation are incipiently uncoiling, and it is often difficult to decide to which of these two ‘species’ they should be referred. It is obvious that such a division is an artificial one, but for the stratigraphic reasons discussed below, it is followed in the present work.

Examination of the stratigraphic ranges of *A. gibber* and *L. nodosa* in South Africa shows them to be very different. *Lenticulina nodosa* first appears in the southern offshore Pletmos, Gamtoos and Algoa basins in the Late Berriasian, initially in small numbers, becoming abundant from the later Early Valanginian to the top of the Early Aptian, at which point it becomes extinct off all three coasts of South Africa. In contrast, *A. gibber* occurs in small numbers, and ranges in South Africa from the mid Valanginian to the Early Aptian, the earlier part of which reflects its occurrence in the Majunga Basin of Madagascar (Cenozones E and F, Late Valanginian to ?Barremian) given by Espitalié & Sigal (1963).

Variation can be seen in the Sundays River Formation tests of *A. gibber* especially in the intensity of the sutural ribbing, the dorsal nodes at the terminations of each suture, and in the size and intensity of the umbilical boss. The number of chambers in the final whorl of the initial coil varies from six to ten. Those with more chambers possess larger-sized initial coils than those with fewer chambers, with the smallest coils being composed of just over one whorl: these differences may reflect dimorphism between the megalospheric and microspheric generations. There appears to be some gradation towards *A. explicatus* Espitalié & Sigal, as occasional tests occur with a longer uncoiled portion and an initial coil of less than one whorl, and ornamented with poorly developed dorsal nodes and raised sutural ribs. These forms (see Fig. 46F–H, J) have for the present been referred to *A. explicatus*, the distinction being made on the size of the initial coil and the strength of the dorsal nodes, but it is clear there is an extremely close relationship between the two species.

### Occurrence

Late Valanginian to ?Barremian (Cenozones E and F), Majunga Basin, Madagascar (Espitalié & Sigal 1963); Oxfordian–Kimmeridgian(?) to Barremian of the Magallanes Basin, southern Chile (Natland *et al.* 1974); Argentina: Valanginian–Hauterivian Pampa Rincón Formation of Tierra del Fuego (Malumián & Masiuk 1975); Barremian Río Mayer Formation, Santa Cruz Province (Malumián & Nañez 1983); also Hauterivian lower Río Mayer Formation (Bertels 1990); Late Valanginian and Early Hauterivian of Meseta Senguerr borehole, Chubut (Masiuk & Viña 1986b); Early Hauterivian of the Agrio Formation, Neuquén Basin (Musacchio 1979, 1981); and early Late Valanginian of the Mngazana Basin, Transkei (McLachlan *et al.* 1976a), early Late Valanginian to Late Hauterivian (Biozones D to ?II) in Pletmos Basin borehole PB–A1, and in the earliest Late Valanginian (Biozone D) Brenton Formation of the southern Cape, South Africa (McLachlan *et al.* 1976b, and supplementary data). The species is widely distributed in continental-shelf and uppermost slope deposits from the earliest Late Valanginian to the Early Aptian in the offshore Pletmos, Gamtoos and Algoa basins off the south Cape coast, South Africa.

### Stratigraphic range in the Sundays River Formation

Late Valanginian to Late Hauterivian (basal Biozone Bb to Biozone I), but generally rare in the Early Hauterivian. The species is typical of inner to outer shelf environments, and is not seen in marginal marine or hypersaline facies.

*Astacolus schloenbachi* (Reuss, 1863)

Figs 46I–M

*Cristellaria schloenbachi* Reuss, 1863, 65, pl. 6 (figs 14–15).

*Cristellaria schloenbachi* Reuss. Chapman, 1894c: 650, pl. 9 (fig. 9a–b).

*Cristellaria* D102 Hecht, 1938: pl. 19b (figs 20–21).

*Lenticulina (Astacolus) schloenbachi* (Reuss). Bartenstein & Brand, 1951: 286, pl. 5 (figs 124a–b, 125a–b).



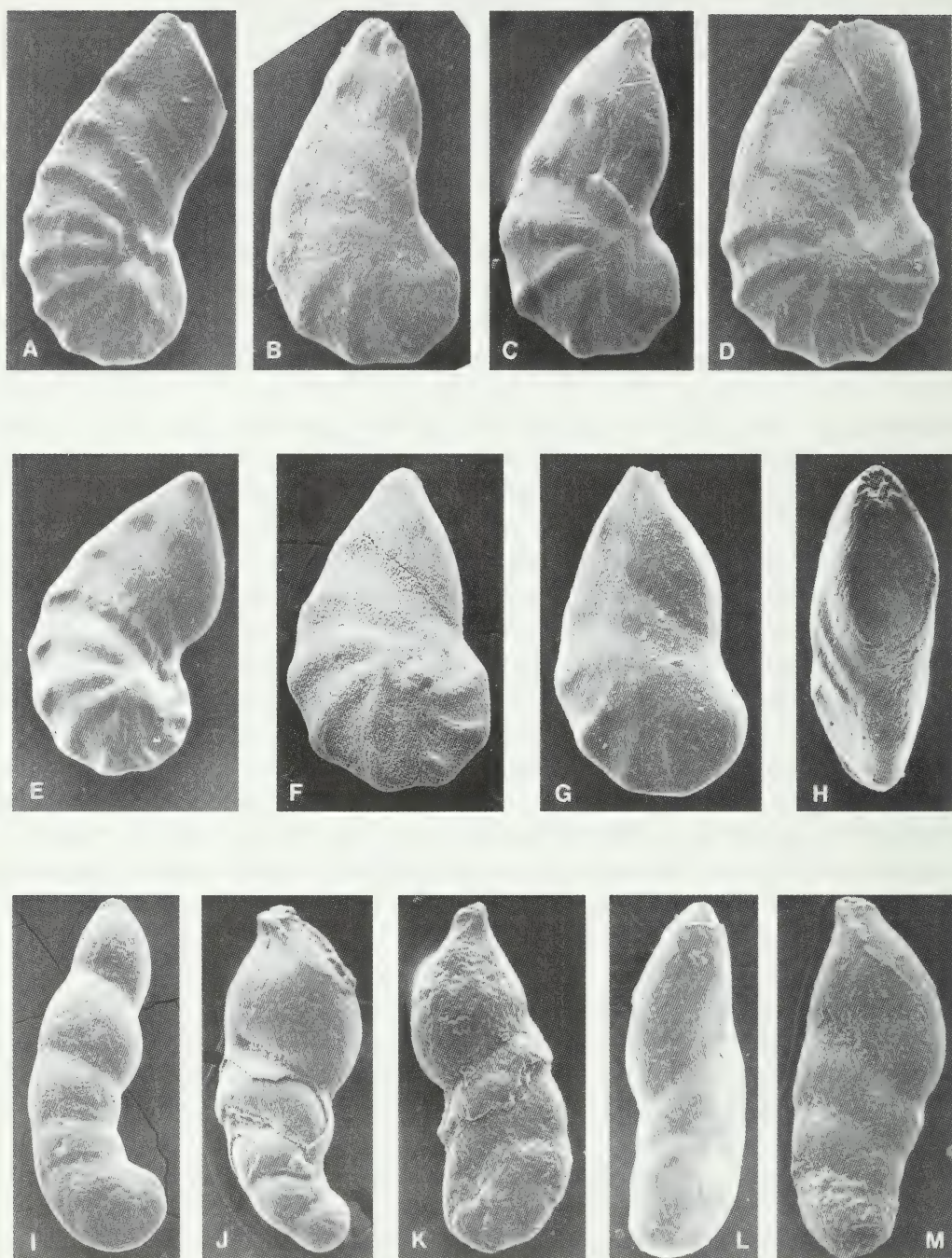


Figure 46.

- Astacolus schloenbachi* (Reuss). Szejn, 1957: 47, 223, pl. 5 (fig. 40). McLachlan *et al.* 1976b: 353, fig. 11 (nos 26–27). Musacchio, 1979: 258, pl. 4 (fig. 22); 1981: pl. 1 (fig. 8).
- Lenticulina* (*Marginulina*) aff. *schlönbachi* (Reuss). Damotte & Magniez-Jannin, 1973: 29, text-fig. 15.
- Lenticulina*/*Marginulina*/*schlönbachi* (Reuss). Magniez-Jannin, 1975: 133, text-fig. 62.
- Astacolus* sp. McLachlan *et al.*, 1976a: 330, fig. 16 (no. 7).
- Lenticulina* (*Astacolus*) *schloenbachi* (Reuss). Bartenstein & Kovatcheva, 1982: 640, pl. 2 (fig. 35).

### Remarks

A considerable degree of variation is evident in authors' interpretations of this species, as listed above. In the Sundays River Formation material, it has proven difficult to draw a distinction between the *Astacolus calliopsis* (Reuss) group and this species. The original illustrations provided by Reuss (1863) of the two species suggest that *A. schloenbachi* displays slightly more inflated chambers than does *A. calliopsis*, the inflation being evident along both the ventral, and more particularly the dorsal outline of the test. The Sundays River Formation tests of *A. schloenbachi* have thus been separated from *A. calliopsis* essentially on the presence of a lobate dorsal margin of the test, reflecting the stronger inflation of the chambers and the correspondingly more depressed sutures of the uncoiled part of the test. Being thus separated, tests of *A. schloenbachi* show a fair degree of variation in the nature of the initial coil. Some specimens show only slight arching of the early chambers (Fig. 46M), whereas others possess a coil of about three-quarters of a whorl (Fig. 46I, K, L).

### Occurrence

Originally described by Reuss (1863) from the upper Hils Clays and the 'Speeton Clay' of the northern German Early Cretaceous. Later occurrences include: Gault Clay (Albian) of Folkestone (Chapman 1894c); Early Hauterivian (Hecht 1938), Middle and Late Valanginian (Bartenstein & Brand 1951) and throughout the Early Cretaceous (Bartenstein & Kovatcheva 1982) of north-western Germany; the Albian (Magniez-Jannin 1975) and the Early Aptian (Damotte & Magniez-Jannin 1973) of the Aube region,

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Fig. 46 (*see facing page*). A–H. *Astacolus gibber* Espitalié & Sigal. A. SAM–PQ–MF1316, side view, AL 1/69, 4 110 feet (A), F551. × 63. B. SAM–PQ–MF1317, side view, AL 1/69, 1 600 feet (VI), F437. × 59. C. SAM–PQ–MF1318, side view, AL 1/69, 1 600 feet (VI), F438. × 76. D. SAM–PQ–MF1319, side view, AL 1/69, 1 570 feet (VI), F428. × 59. E. SAM–PQ–MF1320, side view, AL 1/69, 1 030 feet (III), F311. × 43. F. SAM–PQ–MF1321, side view, Coega Brick Pits outcrop sample 11436 (Bb), F158. × 66. G. SAM–PQ–MF1322, side view, AL 1/69, 520 feet (I), F128. × 76. H. SAM–PQ–MF1323, apertural view, AL 1/69, 580 feet (II), F170. × 71. I–M. *Astacolus schloenbachi* (Reuss). I. SAM–PQ–MF1324, side view, CO 1/67, 660 feet (VII), F146. × 57. J. SAM–PQ–MF1325, side view, AL 1/69, 1 240 feet (IV), F358. × 147. K. SAM–PQ–MF1326, side view, AL 1/69, 4 050 feet (A), F548. × 117. L. SAM–PQ–MF1327, side view, AL 1/69, 910 feet (III), F272. × 100. M. SAM–PQ–MF1328, side view, AL 1/69, 1 570 feet (VI), F433. × 138.



France; the Infra-valanginian (?Berriasian) and the Late Valanginian of central Poland (Sztejn 1957); Late Barremian to Clansayesian (Late Aptian) of Bulgaria (Bartenstein & Kovatcheva 1982); Late Berriasian to mid-Hauterivian in the Speeton Clay of the Yorkshire coast, England (Fletcher 1973); the Late Hauterivian of the Agrio Formation, Neuquén, Argentina (Musacchio 1979, 1981); and the Late Valanginian (Biozone B) of the Mngazana Basin, Transkei, South Africa (McLachlan *et al.* 1976*a*) and the Late Hauterivian (Biozone III) of borehole PB-A1, Pletmos Basin, off the south coast of South Africa (McLachlan *et al.* 1976*b*).

#### *Stratigraphic range in the Sundays River Formation*

Always rare and infrequent, *Astacolus schloenbachi* ranges from Late Valanginian Biozone Bb to Late Hauterivian Biozone I. It is widely distributed, from marginal marine to outermost shelf locations, but is absent in hyposaline environments.

#### *Astacolus calliopsis* (Reuss, 1863) *s.l.*

Fig. 47A–J

*Marginulina linearis* Reuss, 1863: 60, pl. 5 (fig. 15a–b).

*Marginulina calliopsis* Reuss, 1863: 60, pl. 5 (fig. 16a–b).

*Cristellaria parallela* Reuss, 1863: 67, pl. 7 (figs 1, 2a–b).

*Lenticulina* (*Astacolus*) *calliopsis* (Reuss). Bartenstein & Brand, 1951: 286, pl. 5 (figs 120a–c, 121a–b, 122a–b). Bartenstein *et al.*, 1966: 149, pl. 2 (figs 151–154, 169–173). Beer, 1970, pl. 2 (figs 4a–c, 5a–b, 6a–b).

*Marginulina* cf. *inconstantia* (Cushman). Rigassi, 1970, pl. 83 (*pars*).

*Astacolus* cf. *calliopsis* (Reuss). Dailey, 1973: 60, pl. 8 (fig. 5). Musacchio, 1979: 258, pl. 4 (figs 9–10).

*Astacolus calliopsis* (Reuss). McLachlan *et al.*, 1976*a*: 328, fig. 16 (no. 4); 1976*b*: 352, fig. 11 (nos 8–9). Bertels, 1990: 253, pl. 1 (fig. 11).

#### *Remarks*

Authors' use of the name has been followed here, in preference to the seldom used name *Marginulina linearis*. Variation is evident in the degree of coiling in the early part of the test, in the degree of depression along the sutures, and in the compression of the test. It is thus not possible to use the name precisely, as previously used in the European literature.

Sundays River Formation tests referred to *Astacolus calliopsis* *s.l.* show as great a range of variation as that seen in the literature. They appear to be closest to the north-west German forms illustrated by Bartenstein & Brand (1951, pl. 5 (figs 121a–b, 122a–b)), which themselves are close to the *Cristellaria parallela* end-member of this species complex. It is difficult to separate the Sundays River forms from *A. schloenbachi* (Reuss) in one respect (see previously), and from *A. explicatus* Espitalié & Sigal in another.

*Astacolus calliopsis* *s.l.* tests can be distinguished from *A. explicatus* *s.l.* tests in the Sundays River Formation by their smaller initial coil, which is rarely more complete than



three-quarters of a whorl. Most tests exhibit only a quarter to half a whorl. Chambers in the later part of the test are rather more inflated, and the tests are generally not as compressed, nor as wide, especially in the uncoiled portion, as those considered typical of *A. explicatus* s.l. The sutures are usually flush to depressed, whereas those of *A. explicatus* s.l. tend to be flush to weakly raised. However, in both the *A. calliopsis* and *A. explicatus* species-groups, such a range of variation occurs that it has proved very difficult to make an effective division between the two.

### Occurrence

Reuss (1863) described *Marginulina linearis* and *M. calliopsis* from the Minimus Clays, and *Cristellaria parallela* from the upper Hils Clays of the northern German Early Cretaceous. Bartenstein & Brand (1951) regarded the stratigraphic range of *A. calliopsis* in northern Germany as mid-Valanginian to Early Hauterivian. Other records include: Late Aptian to middle Early Albian Maridale Formation of Trinidad (Bartenstein *et al.* 1966); Late Aptian to Early Albian Aiken Member of the Budden Canyon Formation of California (Dailey 1973); Late Hauterivian of the Agrio Formation, Neuquén, Argentina (Musacchio 1979); Hauterivian and ?Barremian lower Río Mayer Formation, southern Argentina (Bertels 1990); and Late Valanginian (Biozone B) of Mngazana Basin, Transkei (McLachlan *et al.* 1976a) and the Late Valanginian to Late Hauterivian (Biozones B to III) of Pletmos Basin borehole PB-A1 (McLachlan *et al.* 1976b).

### Stratigraphic range in the Sundays River Formation

*Astacolus calliopsis* s.l. ranges from Late Valanginian Biozone B to Late Hauterivian Biozone I, with rare examples too in the earlier Late Valanginian Biozone C. The plexus is very variable in its abundance through its range, and may locally dominate assemblages, as seen in its distribution through cored borehole CO1/67. It occurs in most marine environments on the shelf, being absent only in marginal marine, hyposaline conditions.

### *Astacolus explicatus* Espitalié & Sigal, 1963 s.l.

Figs 48A–K

*Astacolus explicatus* Espitalié & Sigal, 1963: 41, pl. 17 (figs 6a–d, 7a–b). Malumián & Masiuk, 1975: 584, pl. 2 (fig. 9).

*Marginulina* cf. *inconstantia* (Cushman). Rigassi, 1970: pl. 83 (*pars*).

see *Astacolus explicatus* (*non* Espitalié & Sigal): McLachlan *et al.*, 1976b: 353, fig. 11 (nos 20–21).

see *Astacolus gibber* cf. *barremianus* (*non* Espitalié & Sigal): Malumián & Nañez, 1983: 383, pl. 2 (fig. 9).

### Remarks

A large group of *Astacolus* specimens from the Sundays River Formation, generally lacking a full initial coil of chambers, and with poorly developed nodes along the dorsal margin of the test, appears best referable to *A. explicatus* s.l. This group is, by and large,

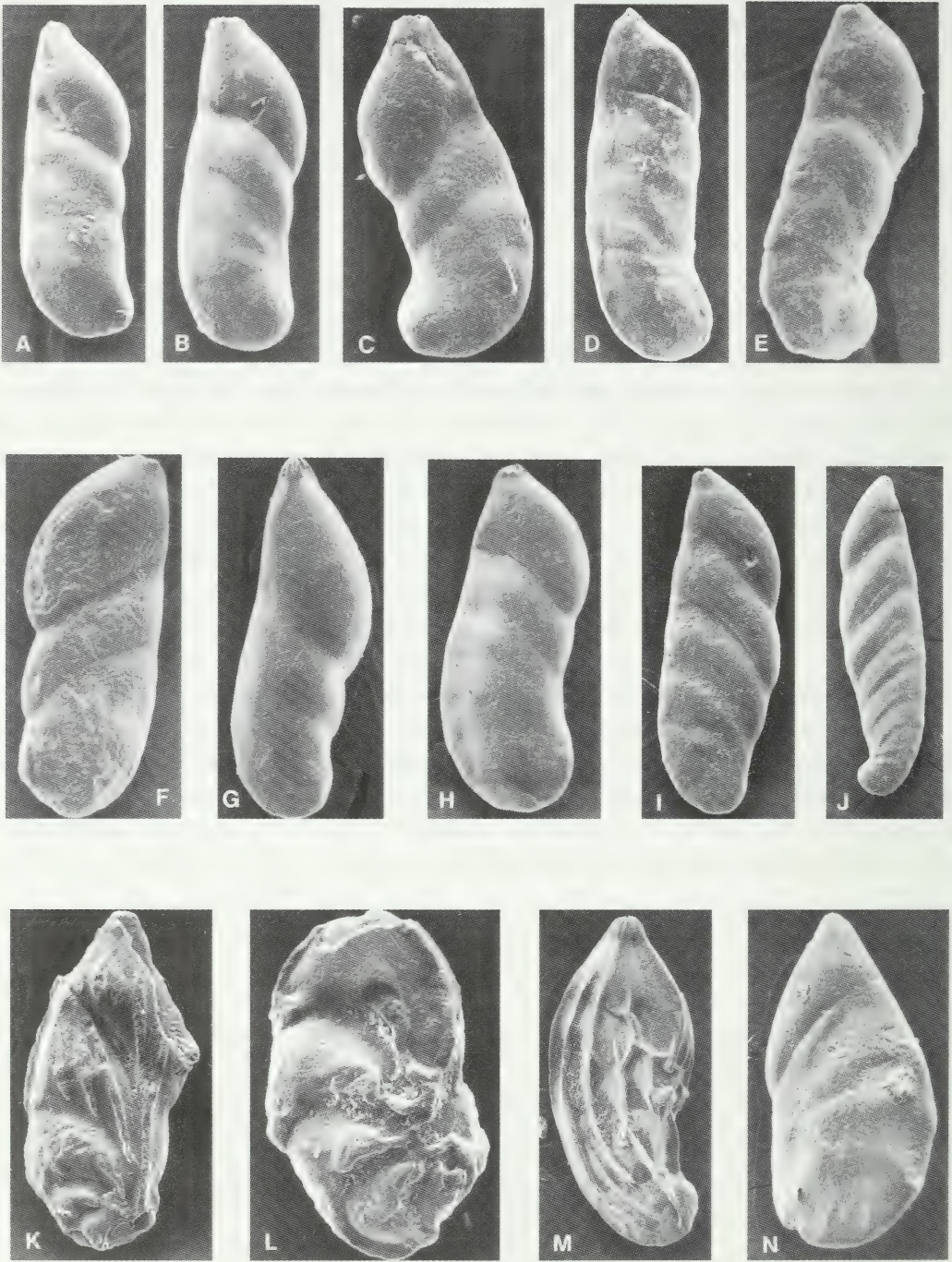


Figure 47.



distinct from *A. gibber* Espitalié & Sigal, although gradational tests do occur, as discussed for that species.

In their manner of uncoiling, tests of this group compare well with the illustrated tests of *A. explicatus* from the Majunga Basin (Espitalié & Sigal 1963). However, occasional specimens (see Fig. 48F–H) suggest a similarity with *A. barremianus* (Michael), described from the north-west German Barremian (Michael 1967) and later from the early Middle Barremian of Heligoland in the North Sea (Bartenstein & Kaever 1973). Both Bartenstein & Kaever (1973) and Malumián & Nañez (1983) have considered *A. barremianus* and *A. gibber* to be morphologically similar, and *A. explicatus* is not far from either in its morphology. In the meantime, the name *A. explicatus* s.l. has been utilized for this group in the Sundays River Formation, but it is clear that more detailed work is required to resolve aspects of the relationships of these three species.

The specimen illustrated by McLachlan *et al.* (1976b, fig. 11 (nos 20–21)) as *A. explicatus* is rather different from either Sundays River Formation or Majunga Basin tests in that it lacks the nodose dorsal margin, possesses strongly raised sutures, and is rather more compressed than is typical, with a subrounded and acute margin to the test (see also Remarks to *Planularia* sp. B).

### Occurrence

Espitalié & Sigal (1963) described *Astacolus explicatus* from Cenozoone F (Late Hauterivian to ?Barremian) of the Majunga Basin, Madagascar. Other records include the Valanginian–Hauterivian Pampa Rincón Formation of Tierra del Fuego, Argentina (Malumián & Masiuk 1975). Specimens of *A. explicatus* s.l. occur extensively in the earlier Cretaceous of the offshore Pletmos, Gamtoos and Algoa basins of South Africa but, because of the difficulties in defining the limits of the plexus, it is of little stratigraphic value. The plexus is best represented from the Early Valanginian to the Late Hauterivian, with rarer occurrences in the Early Barremian, but in older rocks, additional complications arise between it and similar Late Jurassic forms.

### Stratigraphic range in the Sundays River Formation

Late Valanginian Biozone C to Late Hauterivian Biozone I, locally abundant. A very

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Fig. 47 (see facing page). A–J. *Astacolus calliopsis* (Reuss) s.l. A. SAM-PQ-MF1329, side view, AL 1/69, 1 480 feet (IV), F388. × 84. B. SAM-PQ-MF1330, side view, AL 1/69, 1 480 feet (IV), F381. × 78. C. SAM-PQ-MF1331, side view, MV 1/79, 160 m (X), F596. × 160. D. SAM-PQ-MF1332, side view, AL 1/69, 700 feet (II), F210. × 60. E. SAM-PQ-MF1333, side view, AL 1/69, 2 000 feet (VII), F479. × 112. F. SAM-PQ-MF1334, side view, AL 1/69, 2 000 feet (VII), F482. × 116. G. SAM-PQ-MF1335, side view, AL 1/69, 1 570 feet (VI), F429. × 97. H. SAM-PQ-MF1336, side view, AL 1/69, 1 240 feet (IV), F363. × 59. I. SAM-PQ-MF1337, side view, MV 1/79, 140 m (X), F583. × 73. J. SAM-PQ-MF1338, side view, CO 1/67, 642 feet (VII), F143. × 42. K. *Astacolus* sp. A, SAM-PQ-MF1339, side view, MV 1/79, 90 m (X), F577. × 93. L. *Lenticulina* sp. A, SAM-PQ-MF1405, side view, MV 1/79, 350–360 m (Ba), F657. × 150. M. *Astacolus* sp. D, SAM-PQ-MF1340, side view, Zoetgeneugd Cliff outcrop sample 11450 (Bb), F229. × 88. N. *Astacolus* sp., SAM-PQ-MF1341, side view, AL 1/69, 1 360 feet (IV), F368. × 89.



widespread species, ranging from marginal marine to outermost shelf, but absent in hyposaline conditions.

*Astacolus* sp. A

Fig. 47K

*Remarks*

Only three poorly preserved specimens of this species have been recovered. The flat to inflated ventral margin, bordered by two peripheral ribs, perhaps leads one to refer this species to *Saracenaria* rather than *Astacolus*, but the flat ventral face is too narrow for it to be an indisputable *Pravoslavlevia* or *Saracenaria*, and allocation to the genus *Astacolus* is preferred.

The specimens are reminiscent of *Lenticulina/Saracenaria/vestita* (Berthelin) subsp. *vestita*, described by Magniez-Jannin (1975, pl. 13 (figs 6a–b, 7–10)) and by Jannin (1968), although there are clear differences. Besides the peripheral ventral rib, most chambers of the uncoiled part of the test exhibit 2–3 ribs that are always confined to one chamber, and die out just short of the depressed or incised sutures. In contrast, *Saracenaria vestita* is characterized by only one such rib per chamber. Both species are distinguished by rather bladed dorsal keels and by depressed sutures. All specimens of *Astacolus* sp. A are from the Early Hauterivian (Biozones IX and X) of the Sundays River Formation.

*Astacolus* sp. D

Fig. 47M

*Remarks*

One well-preserved example of an elongate *Astacolus* or *Marginulina*, with an ovate to sub-circular cross-section to the uncoiled part of the test, from sample 11450, Zoetgeneugd Cliff (earliest Biozone Bb, Late Valanginian). The surface ornamentation of few, often rather irregular ribs is intense, the ribs themselves being markedly bladed. Chambers are weakly inflated, particularly in the final part of the test; sutures, which are not clear without moistening the test, are flush to weakly depressed and slightly arched.

The surface ornament of vertically aligned, curved ribs is not as orderly as that of *Lenticulina/Marginulina acuticosta* (Reuss) subsp. *restricta* Magniez-Jannin (1975), described from the Albien of France. There is perhaps also some similarity with the *Lenticulina* (*Marginulinopsis*) sp. illustrated by Bartenstein *et al.* (1957: 32, pl. 6 (fig. 122a–b)) from the middle Middle to Late Barremian of the Cuche Formation of Trinidad, but the surface ribs reach close to the aperture and are distributed equidistantly over the surface of the final chamber, neither of which feature is evident on the Sundays River specimen.

*Astacolus* spp.

Fig. 47N

*Remarks*

Small numbers of smooth and unornamented, rather compressed *Astacolus* specimens occur through most of the more normal marine Sundays River Formation. Some, such as that illustrated, may be referable to *A. grata* (Reuss), and thus be comparable with the specimen illustrated by McLachlan *et al.* (1976b, fig. 11 (no. 19)). Others are certainly juveniles that display insufficient diagnostic features for them to be assigned to species, and still others are too poorly preserved to allow a full identification.

Genus *Citharina* d'Orbigny, 1839*Citharina* sp. A

Fig. 48L

*Remarks*

A single specimen from Zoetgeneugd Cliff outcrop (Biozone C, Late Valanginian) is distinguished by its slightly inflated chambers and weakly depressed sutures. The surface ornamentation of distinct and sharply defined, vertically aligned ribs tend to be entirely absent over the sutures. The dorsal margin is carinate and bladed and, for portions of its length, it is irregularly tricarinate. The ventral margin is weakly lobate and rounded in cross-section. The restriction of the surface ribs to the inter-sutural areas occurs, although to a lesser degree, in *Vaginulina* sp. 3309 of Espitalié & Sigal (1963: 48, pl. 20 (fig. 16)). However, the arrangement of the ribs, which spread out towards the dorsal and ventral margins of the test in a fan, and their density are substantially different from that seen in the Zoetgeneugd test.

*Citharina pseudostriatula* Bartenstein & Brand, 1951

Figs 48M–N, 49A–B

*Citharina pseudostriatula* Bartenstein & Brand, 1951: 298, pl. 7 (fig. 182a–b), pl. 12A (fig. 339a–b). Szejn, 1957: 68, 239, pl. 7 (fig. 67). Bartenstein & Kaever, 1973: 227, pl. 3 (figs 42–43).

see *Vaginulina* aff. *pseudostriatula* (Bartenstein & Brand). Espitalié & Sigal, 1963: 51, pl. 22 (fig. 15).

*Citharina striatula* (non Roemer): Beer, 1970: 16, pl. 3 (fig. 2a–b).

see *Citharina pseudostriatula* Bartenstein & Brand. Hart *et al.*, 1981: 159, pl. 7.6 (figs 12–13).

*Remarks*

The holotype of *Citharina pseudostriatula* (Bartenstein & Brand, 1951, pl. 12A (fig. 339a–b)) is characterized by its numerous fine ribs ornamenting the surface of the test. The marginally sited ribs are aligned parallel to the test periphery; additional ribs appear, or bifurcate from earlier ribs as the number of chambers increases. This species



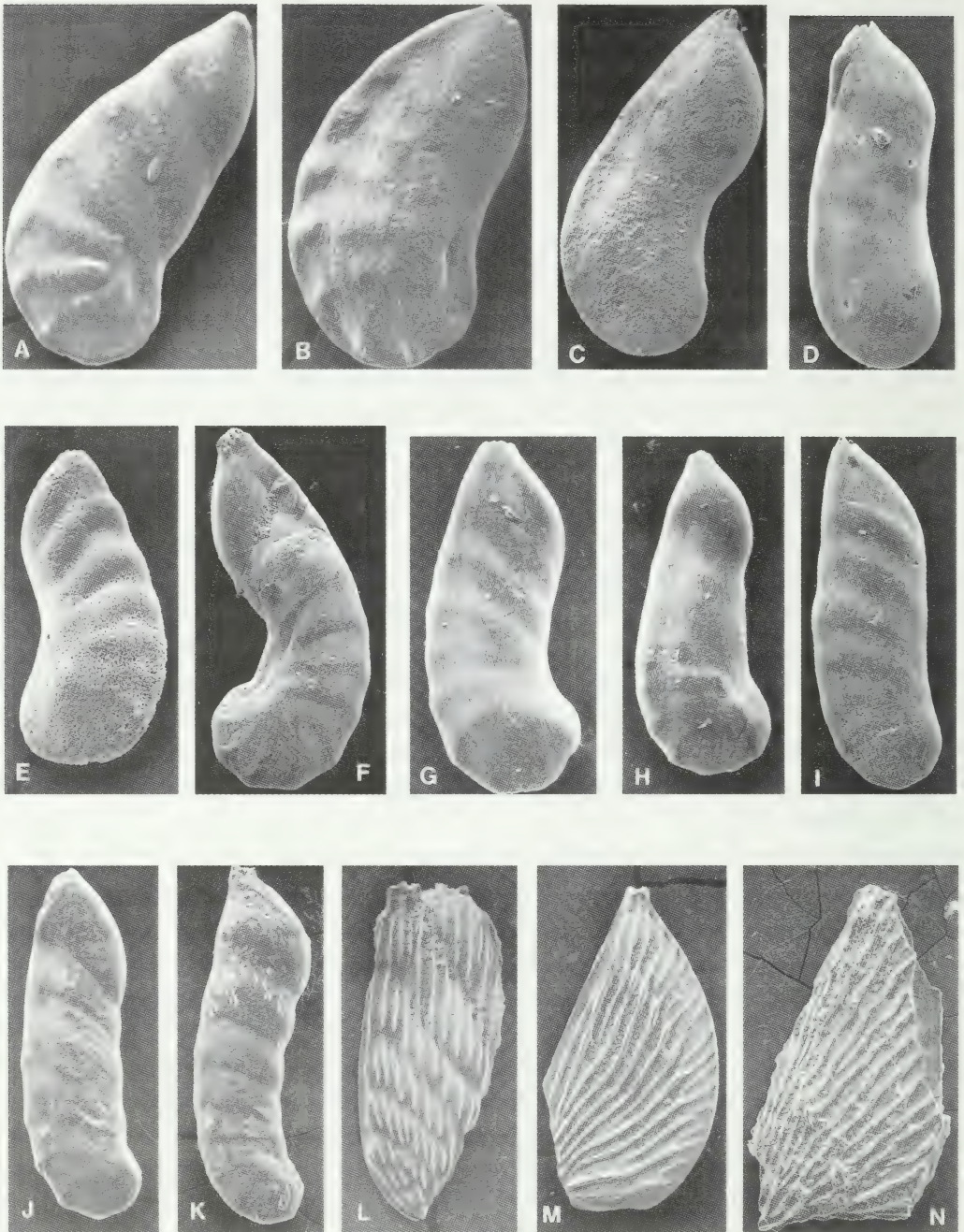


Figure 48.



appears to be closely related to *C. harpa* (Roemer), which is distinguished by its ribs being more solidly built, and by the absence of bifurcating or additional ribs. For this reason, the illustrations of *C. pseudostriatula* given by Hart *et al.* (1981, pl. 7.6 (figs 12, 13)) appear a little too close to *C. harpa* in their arrangement of ribs. Bartenstein & Brand (1951) noted that a number of references to *C. harpa* in the Late Dogger and Malm of Europe should be re-allocated to *C. pseudostriatula*. The South African tests compare well with the European illustrations of this species.

### Occurrence

*Citharina pseudostriatula* is widely known in the Jurassic and Early Cretaceous of Europe: Late Dogger to latest Valanginian of north-west Germany (Bartenstein & Brand 1937, 1951); Hauterivian of Lincolnshire, England (Bartenstein 1956); Berriasian to later Hauterivian of the Speeton Clay, Yorkshire coast, England (Fletcher 1973); Late Hauterivian of Heligoland (Bartenstein & Kaever 1973); and Infravalanginian (?Berriasian) to Hauterivian of central Poland (Sztejn 1957). A very similar form occurs high in Cenozoone F (?Barremian) of the Majunga Basin, Madagascar (Espitalié & Sigal 1963).

### Stratigraphic range in the Sundays River Formation

This species occurs rarely, from the lowest Biozone Bb of the Late Valanginian to mid-Biozone VI of the Late Hauterivian. There are no Early Hauterivian records, and it seems likely that it is confined to specific intervals of short duration in the Sundays River sequence. *Citharina pseudostriatula* occurs in marginal marine and middle- to outer-shelf environments, but is absent in both hypersaline and reduced-oxygen environments.

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Fig. 48 (see facing page). A–K. *Astacolus explicatus* Espitalié & Sigal *s.l.* A. SAM–PQ–MF1342, side view, AL 1/69, 1 750 feet (VII), F456. × 83. B. SAM–PQ–MF1343, side view, AL 1/69, 1 930 feet (VII), F469. × 75. C. SAM–PQ–MF1344, side view, shallow borehole SB–8, core ?, top (III), F665. × 74. D. SAM–PQ–MF1345, side view, shallow borehole SB–35, core ?, top (III), F702. × 65. E. SAM–PQ–MF1346, side view, Zoetgeneugd Cliff outcrop sample 11450 (Bb), F236. × 68. F. SAM–PQ–MF1347, side view, shallow borehole SB–32, core 2, ?199 feet, ?bottom (IV), F699. × 48. G. SAM–PQ–MF1348, side view, AL 1/69, 670 feet (II), F204. × 61. H. SAM–PQ–MF1349, side view, AL 1/69, 670 feet (II), F203. × 41. I. SAM–PQ–MF1350, side view, shallow borehole SB–35, core ?, top (III), F700. × 58. J. SAM–PQ–MF1351, side view, AL 1/69, 700 feet (II), F211. × 51. K. SAM–PQ–MF1352, side view, CO 1/67, 642 feet (VII), F142. × 46. L. *Citharina* sp. A. SAM–PQ–MF1353, side view, Zoetgeneugd Cliff outcrop sample 11452 (C), F254. × 65. M–N. *Citharina pseudostriatula* Bartenstein & Brand. M. SAM–PQ–MF1354, side view, Zoetgeneugd Cliff outcrop sample 11450 (Bb), F231. × 57. N. SAM–PQ–MF1355, side view, CO 1/67, 520 feet (VI), F134. × 58.

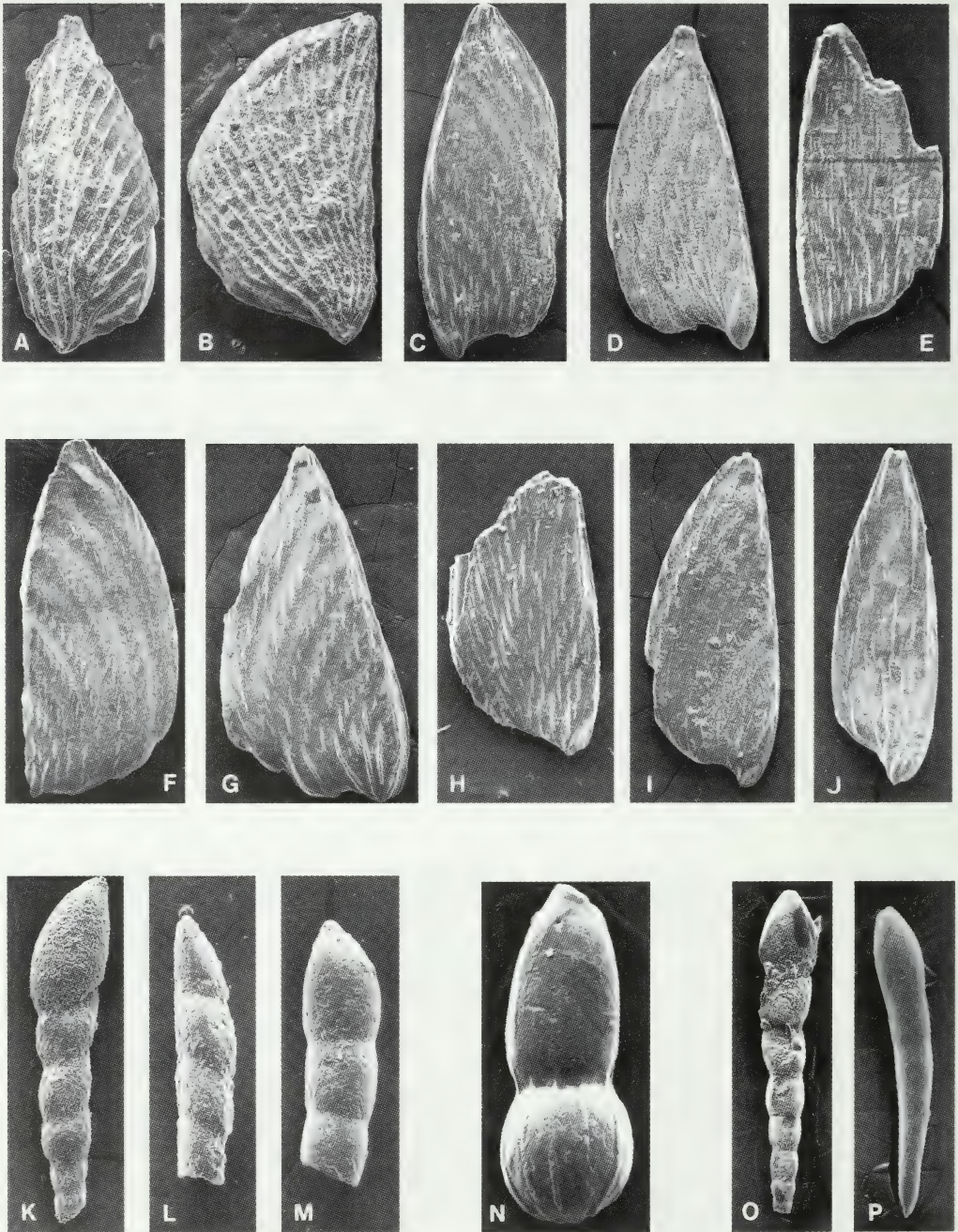


Figure 49.



*Citharina austroafricana* sp. nov.

Figs 49C–J

*Citharina* cf. *C. cristellarioides* (Reuss). Rigassi, 1970: pl. 83 (*pars*).*Citharina sparsicostata* (non Reuss): McLachlan *et al.*, 1976a: 330, fig. 16 (no. 8); 1976b: 356, fig. 12 (nos 22–23).*Citharina cristellarioides* (non Reuss): McLachlan *et al.*, 1976b: 355, fig. 12 (nos 20–21).*Diagnosis*

A strongly compressed species of *Citharina* possessing an irregularly tricarinate dorsal margin; ornamented over each chamber with a narrow band of closely spaced ribs, generally vertically aligned, and with occasional more elongate ribs developed over several chambers close to the dorsal margin and the proloculus.

*Etymology*

Named for its widespread distribution in the Pletmos, Gamtoos, Algoa and Mngazana basins around South Africa.

*Material*

*Holotype* (Fig. 49F). MF1361, SOEKOR negative F215.

*Paratypes* (Fig. 49C–E, G–J). MF1358 to MF1360, MF1362 to MF1365, seven specimens, SOEKOR negatives F132, F80, F213, F140, F263, F133, and F234. Four additional paratypes are illustrated in the work by McLachlan *et al.* (1976b, fig. 12 (nos 20–23)) on the Brenton Formation and borehole PB–A1.

*Stratum typicum*

Biozone II, Late Hauterivian, Sundays River Formation.

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Fig. 49 (see facing page). A–B. *Citharina pseudostriatula* Bartenstein & Brand. A. SAM–PQ–MF1356, side view, CO 1/67, 520 feet (VI), F135.  $\times 58$ . B. SAM–PQ–MF1357, side view, CO 1/67, 642 feet (VII), F136.  $\times 39$ . C–J. *Citharina austroafricana* sp. nov. C. Paratype, SAM–PQ–MF1358, side view, CO 1/67, 520 feet (VI), F132.  $\times 30$ . D. Paratype, SAM–PQ–MF1359, side view, Uitenhage to Graaff-Reinet Road outcrop sample 11464 (Bb), F80.  $\times 61$ . E. Paratype, SAM–PQ–MF1360, side view, AL 1/69, 730 feet (II), F213.  $\times 32$ . F. Holotype, SAM–PQ–MF1361, side view, AL 1/69, 760 feet (II), F215.  $\times 28$ . G. Paratype, SAM–PQ–MF1362, side view, CO 1/67, 642 feet (VII), F140.  $\times 40$ . H. Paratype, SAM–PQ–MF1363, side view, AL 1/69, 820 feet (III), F263.  $\times 37$ . I. Paratype, SAM–PQ–MF1364, side view, CO 1/67, 520 feet (VI), F133.  $\times 32$ . J. Paratype, SAM–PQ–MF1365, side view, Zoetgeneugd Cliff outcrop sample 11450 (Bb), F234.  $\times 49$ . K–M. *Dentalina communis* d'Orbigny *s.l.* K. SAM–PQ–MF1366, side view, shallow borehole SB–9A, core 1, 282 feet 6 inches (II), F694.  $\times 55$ . L. SAM–PQ–MF1367, side view, AL 1/69, 370 feet (I), F47.  $\times 68$ . M. SAM–PQ–MF1368, side view, AL 1/69, 370 feet (I), F49.  $\times 63$ . N. *Dentalina* sp. B, SAM–PQ–MF1372, side view, MV 1/79, 240–250 m (A), F623.  $\times 150$ . O–P. *Dentalina* spp. O. SAM–PQ–MF1373, side view, shallow borehole SB–32, core 1, 148 feet (IV) F695.  $\times 58$ . P. SAM–PQ–MF1374, side view, AL 1/69, 520 feet (I), F162.  $\times 80$ .



*Locus typicus*

Borehole AL 1/69, cuttings sample at 760 feet.

*Description*

Test strongly compressed, leaf-like, and irregularly triangular in outline. Dorsal margin initially weakly curved, later straight; ventral margin initially concave, becoming convex, and, in the final part of the test, weakly to strongly lobate. In cross-section, test elongate-rectangular, long sides parallel, with dorsal margin bounded by one rather thick rib that is continuous for most of the height of the test; the rib is low and rounded in cross-section. Two additional ribs are present, one on either side of the thickened rib, and are sub-parallel to it, thus forming an irregularly tricarinate dorsal margin. Ventral margin sub-rectangular to rounded in outline, ornamented with fine rounded ribs at its margins, but smooth and unornamented along a central band for most of its length. Chambers uniserially arranged throughout, arcuate, increasing greatly in width as added, but little in height. Chambers flush, not inflated. Sutures variably evident beneath the surface ornamentation, generally flush, but often becoming weakly depressed between the last few chambers, broad and evenly curved in form. Aperture terminal, close to the dorsal margin of the test; in form a narrow elongate-ovate opening that sometimes shows some indication of a margin of short radiate slits. Surface ornamentation of numerous short ribs, arranged in a broad arc from near the dorsal margin almost to the ventral margin, each rib roughly vertically oriented. Ribs low and rounded in form, but they are often reduced in intensity as a result of post-depositional corrosion of tests. The arc of ribs over each chamber is suspended from the overlying suture, so that the lower third or half of each chamber is usually smooth and unornamented. The chambers in the final part of the test may develop up to 18 ribs each test side. Over the proloculus, and sporadically up the dorsal margin, more elongate ribs occur, which may extend over two chambers, rarely more. The great majority of the surface ribs are aligned parallel to the straight portion of the dorsal margin, wherever they are located. Apical point of test always bluntly rounded.

*Remarks*

Variation in the distribution of the surface ornamentation occurs in the tests from the Sundays River Formation. Occasional Hauterivian examples develop the short vertical ribs over almost the entire chamber height. Late Valanginian tests, and also those from Brenton, generally display a fainter and less organized ribbing pattern and, in such tests, the predominant ribs are the irregular, longer ones close to the proloculus and the dorsal margin (see Fig. 49J in particular).

Examination of true specimens of both *C. sparsicostata* (Reuss) and *C. cristellarioides* (Reuss) from the Hauterivian and Barremian portion of the Speeton Clay, Yorkshire, England, has indicated that the South African tests previously allocated to these two boreal species must be referred elsewhere. As figured by Reuss (1863, pl. 3 (fig. 17a-b)), *C. cristellarioides* is characterized by short ribs developed over the chambers and not over the sutures. In the early part of the Speeton tests, many of the ribs extend over two or more chambers and, in general, a far greater proportion of the test surface of *C. cristellarioides*

is ornamented with ribs than is the case with *C. austroafricana*. Furthermore, because the sutures of the European species lack ribs, they are much more clearly marked than in *C. austroafricana*, and are initially flush, becoming weakly depressed for the last third of the test; the final chambers of the test are always distinctly, but lightly, inflated in *C. cristellarioides*.

South African specimens of *Citharina* previously allocated to *C. sparsicostata* are generally broken fragments of larger tests, comprising the initial part and including the proloculus and five or six subsequent chambers. These damaged tests therefore tend to show the longer ribs of the proloculus and dorsal margins, and possess few of the distinctive arcs of short ribs so typical of adult tests. In addition, true examples of *C. sparsicostata* from Speeton are intensely ornamented: *C. austroafricana* is distinguished by a much lighter, more delicate ornamentation.

*Citharina delicata* Magniez-Jannin (1975: 209, pl. 14 (fig. 8)), from the Albian of the Aube district, France, features a similar surface ornament to that seen on *C. austroafricana*, but differences are evident. The ribs of *C. delicata* are located over the chambers and not over the sutures, but the sutures are marked, in each case, by a fine rib that extends the full length of each suture.

There are a number of references to *C. sparsicostata* and *C. cristellarioides* in Argentina that are of interest. The *C. cristellarioides* tests illustrated by Simeoni (1985, pl. 1 (figs 1–3)) and Musacchio (1979, pl. 4 (fig. 19); 1981, pl. 1 (fig. 2)), although differing in their density of ornamentation, are clearly much closer to the European species than any *Citharina* specimens yet found in the Early Cretaceous of South Africa. However, the shells of *C. sparsicostata* figured by Malumián & Nañez (1983, pl. 1 (figs 15–16)) and by Kielbowicz *et al.* (1983, pl. 1 (figs 10–11)) appear to be referable to *C. austroafricana*, although the preservation of these is rather variable. In contrast, the examples of *C. sparsicostata* and *C. cristellarioides*, illustrated by Espitalié & Sigal (1963) from the Majunga Basin, Madagascar, compare well with the two European species, but *C. austroafricana*, as here defined, is clearly different from either (see Espitalié & Sigal 1963, pl. 21 (figs 9–11 and fig. 12, respectively)).

The specimen of *Citharina* cf. *C. cristellarioides* illustrated by Beer (1970: 15, pl. 3 (fig. 1)) from borehole CO 1/67 is probably referable to *C. austroafricana*, but the ornamentation shown is quite unlike any Early Cretaceous South African specimens of *Citharina* encountered by the present author, and is suspected to be a misrepresentation. The test identified as *Citharina* cf. *C. cristellarioides* by Rigassi (1970, pl. 83) is typical, but another illustrated test, referred to *Citharina* cf. *C. sparsicostata* by Rigassi (1970), is of a very different form, not encountered in the Algoa material available to the author.

### Occurrence

*Citharina austroafricana* is widespread but never abundant. It occurs in the early Late Valanginian (Biozone D) Brenton Formation, and ranges from Late Valanginian Biozone D to Late Hauterivian Biozone II of Pletmos Basin borehole PB–A1 (McLachlan *et al.* 1976b); the Late Valanginian (Biozone B) of the Mngazana Basin, Transkei (McLachlan *et al.* 1976a); and in the offshore Pletmos, Gamtoos and Algoa basins. Its full

range appears to be early Valanginian to Early Barremian, although it is very rare in the Barremian.

*Stratigraphic range in the Sundays River Formation*

Late Valanginian Biozone Bb to Late Hauterivian Biozone I. The species occurs from marginal marine to outermost shelf environments, but appears to be commonest in shallow marine, well-oxygenated localities affected by turbulence and with a silty or sandy substrate. It is absent in both hyposaline and low-oxygen conditions.

Genus *Dentalina* Risso, 1826 *s.l.*

Loeblich & Tappan (1988) have promoted the subdivision of the genus *Dentalina* (as understood in Loeblich & Tappan 1964) into a variety of more tightly constrained genera. As a consequence, the genus *Dentalina* *sensu stricto* includes only species with a longitudinally costate surface. None of the Sundays River Formation tests display this characteristic, and thus ought to be referred elsewhere. However, since the majority are damaged, with initial chambers often missing and apertural structures incomplete, precise generic allocations of the relatively few specimens found are difficult, and often impossible to achieve. For this reason, the genus *Dentalina* is considered herein in the wide sense, although it seems likely that many of the specimens from the Sundays River Formation ought to be referred to *Laevidentalina* (see Loeblich & Tappan 1988: 396, pl. 439 (figs 22–24)).

*Dentalina communis* d'Orbigny, 1826 *s.l.*

Fig. 49K–M

*Nodosaria (Dentalina) communis* d'Orbigny, 1826: 254.

*Dentalina communis* d'Orbigny. Szejn, 1957: 50, 225, pl. 5 (fig. 41a–b). Beer, 1970: 10, pl. 1 (fig. 6). McLachlan *et al.*, 1976a: 330, fig. 16 (no. 9). Stapleton & Beer, 1977: 2, pl. 3 (fig. 10).

*Remarks*

Scattered examples referable to this species occur widely in the Sundays River Formation. It is clear that this 'species' must be considered a plexus of similar forms, all rather conservative in their morphology, and it is thus regarded here *sensu lato*. The plexus ranges from the Lias through to the present day. None of the Sundays River tests are complete, being usually damaged or broken in the juvenile portion of the test. None display any indication of an initial biserial arrangement of chambers on the dorsal margin of the test, as is typical of *Enantiodentalina communis* Marie (1956).

*Stratigraphic range in the Sundays River Formation*

Sporadic examples occur from the Late Valanginian Biozone Bb to Late Hauterivian Biozone I.



*Dentalina linearis* (Roemer, 1841)

Figs 50A–C

*Nodosaria linearis* Roemer, 1841: 95, pl. 15 (fig. 5).

*Dentalina linearis* (Roemer). McLachlan *et al.*, 1976a: 330, fig. 16 (no. 10). Musacchio, 1979: 258, pl. 4 (fig. 6). Malumíán & Nañez, 1983: 378, pl. 1 (fig. 17).

*Remarks*

This species is infrequent and rather scattered through the Sundays River Formation. Tests are often partially crushed (Fig. 50A), which tends to exaggerate the degree of inflation of the chambers. All well-preserved specimens possess a radiate aperture (Fig. 50C), thus distinguishing them from the otherwise morphologically similar *Lingulonodosaria nodosaria* (Reuss).

*Stratigraphic range in the Sundays River Formation*

Ranges through most of the sequence, from Late Valanginian Biozone Bb to Late Hauterivian Biozone I.

*Dentalina* sp. B

Fig. 49N

*Remarks*

A single specimen from Biozone A (Late Valanginian) of borehole MV 1/79 is characterized by 10 fine vertical ribs on the proloculus, which rapidly fade on the second chamber. The specimen is similar to one example of *Lenticulina/Vaginulina* sp. illustrated by Damotte & Magniez-Jannin (1973, pl. 3 (fig. 45)) from the Aptian of the Aube district, France.

*Dentalina* spp.

Figs 49O–P

*Remarks*

Scattered specimens of *Dentalina* occur throughout most of the studied boreholes. Specimens are usually too few, or too poorly preserved for confident specific identification. All of this group have smooth, unornamented exteriors. Two typical forms are illustrated.

Genus *Frondicularia* Defrance, 1826*Frondicularia nieuwaarskopensis* sp. nov.

Figs 50D–G

*Diagnosis*

A leaf-like, lightly ornamented species of *Frondicularia*, characterized by maximum test width near mid-height, a prominent apical spine, a single short rib ornamenting the

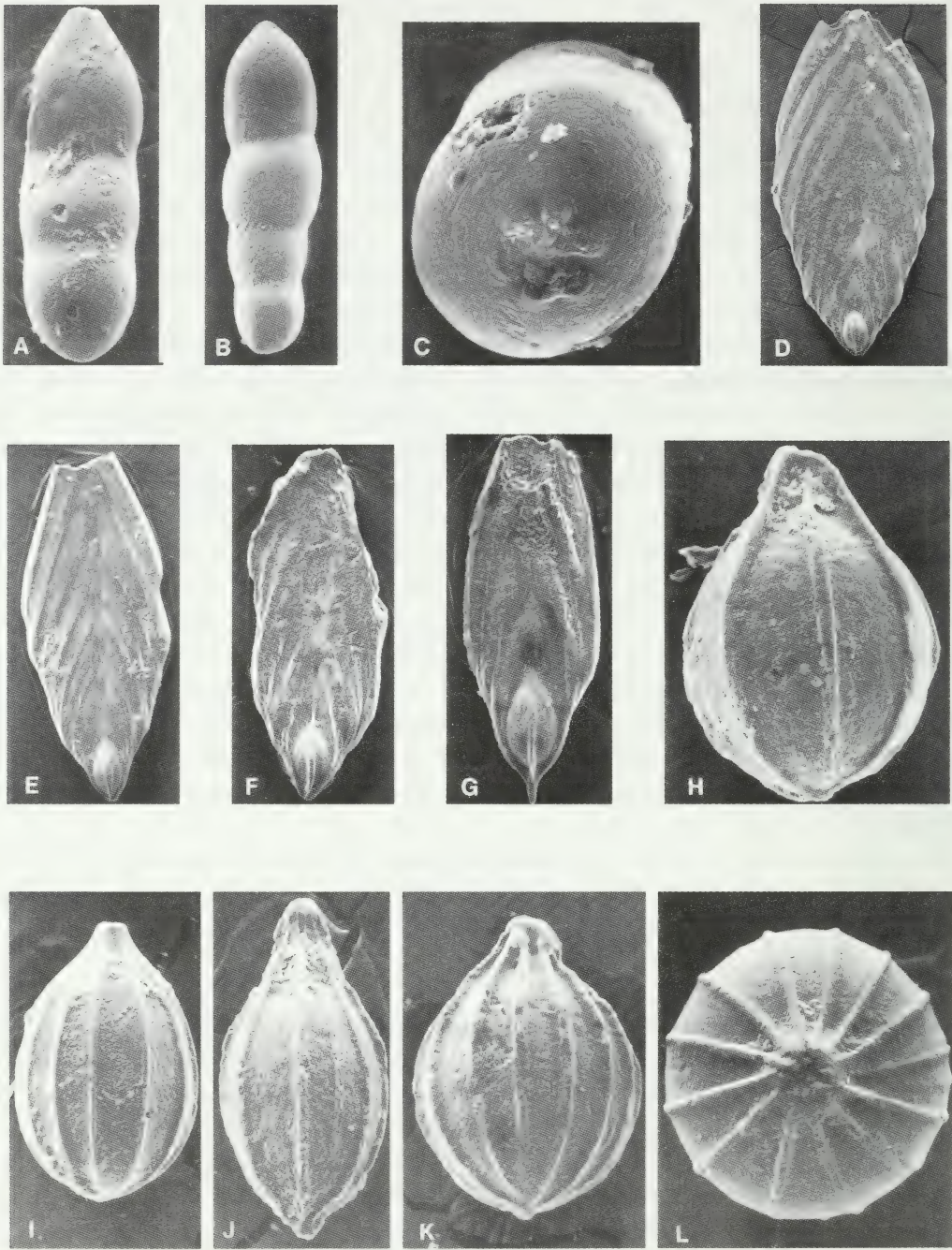


Figure 50.



proloculus on each side of the test, very weak sutural ribs, and occasional short ribs developed on the chambers, especially close to the test periphery.

### Etymology

From the presence of particularly well-preserved specimens from shallow borehole SB-15, drilled on the area of the old farm Nieuwjaarskop, just east of the Sundays River Valley.

### Material

*Holotype* (Fig. 50D). MF1375, SOEKOR negative F131.

*Paratypes* (Fig. 50E–G). MF1376 to MF1378, three specimens, SOEKOR negatives F631, F587, and F688.

### *Stratum typicum*

Biozone VI, early Late Hauterivian, Sundays River Formation.

### *Locus typicus*

Borehole CO 1/67, core sample at 520 feet.

### Description

Test strongly compressed, leaf-like, with flat sides, and a rather foliar outline. Test periphery irregularly lobate; with margin in cross-section being sub-angular to sub-rounded and sub-rectangular, rather thin. Chambers uniserially arranged throughout, with the last-formed ones faintly inflated. The proloculus is always prominent, subglobular to pyriform. All subsequent chambers sagittate, strongly overlapping, with the final chamber extending backwards for one-third to two-thirds of the test height. Proloculus bordered around its lower, exposed side by a rather thick band of shell, with rounded apex and flat sides. Sutures generally distinct, weakly depressed to flush, often slightly limbate, and occasionally with low ribs developed along their length close to the test margin. Aperture terminal, composed of a small circular, possibly radiate opening at the mid-point of the last-formed chamber. Apical point of test ornamented by a short,

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Fig. 50 (see facing page). A–C. *Dentalina linearis* (Roemer). A. SAM-PQ-MF1369, side view, AL 1/69, 520 feet (I), F121.  $\times$  126. B. SAM-PQ-MF1370, side view, AL 1/69, 1 000 feet (III), F285.  $\times$  91. C. SAM-PQ-MF1371, apertural view, MV 1/79, 200–210 m (X), F612.  $\times$  250. D–G. *Frondicularia nieuwaarskopensis* sp. nov. D. Holotype, SAM-PQ-MF1375, side view, CO 1/67, 520 feet (VI), F131.  $\times$  33. E. Paratype, SAM-PQ-MF1376, side view, MV 1/79, 250–260, (A), F631.  $\times$  57. F. Paratype, SAM-PQ-MF1377, side view, MV 1/79, 150 m (X), F587.  $\times$  63. G. Paratype, SAM-PQ-MF1378, side view, shallow borehole SB-15, core 4, 229 feet (II), F688.  $\times$  83. H–L. *Lagena alexandria* sp. nov. H. Holotype, SAM-PQ-MF1379, side view, AL 1/69, 940 feet (III), F274.  $\times$  271. I. Paratype, SAM-PQ-MF1380, side view, AL 1/69, 520 feet (I), F125.  $\times$  143. J. Paratype, SAM-PQ-MF1381, side view, AL 1/69, 460 feet (I), F104.  $\times$  191. K. Paratype, SAM-PQ-MF1382, side view, AL 1/69, 1 750 feet (VII), F455.  $\times$  154. L. Paratype, SAM-PQ-MF1383, apertural view, AL 1/69, 1 060 feet (III), F321.  $\times$  164.



fairly thick, terminally rounded spine: this is usually damaged or snapped off in studied specimens. Surfaces of chambers occasionally weakly ornamented with short, vertically aligned ribs, often most evident close to the test periphery. These ribs never extend for more than one chamber, are low and rounded in section, and may merge with the sutural ribs on occasion. Proloculus ornamented with one short, vertically aligned rib on each side of the test, which often almost develops into a spine at its lower end, while gradually fading away upwards; this prolocular ornament is the most prominent of all the surface costation. One or two specimens also exhibit a short, vertically aligned rib immediately above the highest point of the proloculus, that rapidly widens and subsides in intensity upwards, away from the proloculus.

### Remarks

Species of *Frondicularia* are everywhere very rare in the Valanginian and Hauterivian rocks of South Africa. This may be partly due to the restriction of the genus to oxygenated outermost-shelf and uppermost-slope locations, which have only rarely been intersected in boreholes. Almost all records of *F. nieuwnjaarskopensis* in the Sundays River Formation are confined to the deeper marine borehole intersections close to the present-day coast.

This *Frondicularia* species, like *Citharina austroafricana* sp. nov., is relatively poorly ornamented compared to *Frondicularia* from the Valanginian–Hauterivian of the Majunga Basin or north-west Europe. *Frondicularia nieuwnjaarskopensis* shows some superficial similarities to *F. pectinatimornata* of Espitalié & Sigal (1963: 56, pl. 26 (figs 11–15)), especially in the short ribs developed on the chambers, but it lacks the spinose terminations to the chambers and never displays more than one rib across the inflated proloculus. No obvious similarities can be seen between *F. nieuwnjaarskopensis* and the many varied Early Cretaceous species of the genus known from north-west Europe.

### Stratigraphic range in the Sundays River Formation

Late Valanginian Biozone Bb to Late Hauterivian Biozone I, but never common, and usually absent in the Early Hauterivian. Typical of oxygenated middle- and outer-shelf environments, and for this reason, rarely seen in the Valanginian and Hauterivian of the offshore Pletmos, Gamtoos and Algoa basins.

### Genus *Lagena* Walker & Jacob, 1798 s.l.

### Remarks

The genus *Lagena* is considered here in the wide sense. Although the species of *Lagena* described here that possess an ornamentation of vertically aligned ribs still can be referred to this genus (see Loeblich & Tappan 1988: 415), it seems that *Lagena algoensis* sp. nov. may be better placed within the genus *Pygmaeoseistron*. Specimens of *Lagena hauteriviana hauteriviana* Bartenstein & Brand and *L. h. cylindracea* Bartenstein & Brand, as understood here, may be referable to the genus *Reussolina* but, although they are smooth-walled, with an apical process, and often pyriform in outline, they completely lack the grooves radiating from the aperture that are characteristic of that genus.

*Lagena alexandria* sp. nov.

Figs 50H–L

*Lagena sulcata* s.l. (non Walker & Jacob): Musacchio, 1979: 258, pl. 4 (fig. 23).

*Diagnosis*

A species of *Lagena* distinguished by its subglobular test ornamented with 8–14 vertically aligned ribs that are sharply delineated from the chamber wall, usually rounded in cross-section, and which merge around the aperture.

*Etymology*

Noun in apposition; named from its first appearance in the study in AL 1/69 borehole, which was drilled in the magisterial district of Alexandria.

*Material*

*Holotype* (Fig. 50H). MF1379, SOEKOR negative F274.

*Paratypes* (Fig. 50I–L). MF1380 to MF1383, four specimens, SOEKOR negatives F125, F104, F455, and F321.

*Stratum typicum*

Biozone III, Late Hauterivian, Sundays River Formation.

*Locus typicus*

Borehole AL 1/69, cuttings sample at 940 feet.

*Description*

Test subglobular to elongate-ovate or pyriform, unilocular. Aperture terminal, produced on a short development of the test of variable height; in form a subcircular opening. Surface of test ornamented with 8–14 vertically aligned ribs, which are sharply defined from the remaining, unornamented test surface. Ribs rounded in cross-section, rarely acute, although the difference is probably due to post-depositional leaching of acute ribs. The ribs merge at the apical point of the test, where a short, blunt, rounded apical spine is developed. The ribs also merge around the short development of the test just below the aperture, where, in most examples, a poorly developed thickening or rib encircles the aperture and links all the vertical ribs. In occasional examples, the apertural area lacks this encircling ornament. Test moderate in thickness.

*Remarks*

This species is considered to include the specimen illustrated by Musacchio (1979) from the Late Hauterivian of Neuquén Province, Argentina, as *Lagena sulcata* (Walker & Jacob) *sensu lato*. However, the Argentinian test seems to possess rather more bladed ribs than the tests of *L. alexandria* typical of the Sundays River Formation. The difference is regarded as being due to calcite dissolution of the peak of each rib, thus rounding a

previously angled ornamentation. Slight differences exist in the paratypes illustrated but the holotype (Fig. 50H) is representative of the commonest form in the Sundays River Formation, and is closest to the Argentinian specimen. A similar form, with fewer ribs, has been illustrated as *Lagena* sp. 3 by Jones & Wonders (1992: 563, pl. 2 (fig. 9)) from the Berriasian–Valanginian Barrow Group off north-west Australia. A further, closely related form is that illustrated as *L. sulcata* by Lofaldli & Thusu (1979, pl. 46 (fig. 19)) from the Valanginian–Hauterivian Nybrua Formation of Andøya, northern Norway.

There are a number of scattered references to *Lagena* forms resembling *L. sulcata* (Walker & Jacob) in the Early Cretaceous at many widely spaced localities. However, examination of these, and comparison with extant *L. sulcata* from the coastline of the British Isles, indicate that most, if not all, can be readily separated from the living species. *Lagena sulcata*, first described from the shore sands of Sandwich in Kent, England, by Walker & Jacob (*in* Kanmacher 1798), is characterized by about 25 narrow-bladed costae (Haynes 1973). The Late Hauterivian forms here described as *L. alexandria* differ from the tests of *Lagena* cf. *sulcata* from the Late Valanginian Biozone B deposits of the Mngazana Basin (McLachlan *et al.* 1976a: 330, fig. 16 (nos 13–14)). The Mngazana species is characterized by a prominent apertural neck and apical tube, and its ribs are formed as a continuation of the test surface, rather than as in *L. alexandria*, where a distinct groove beside each rib sharply delineates the ribs from the remainder of the test surface (see Fig. 50H in particular). Morphologically similar forms to the Mngazana species occur widely in the Early Valanginian of the offshore Gamtoos Basin, but generally possess about 15 rather than the ten or so ribs of the Mngazana tests. It is clear that the Mngazana material warrants a new name, although this aspect is held over for the moment. The Mngazana species has not been found in the Sundays River Formation of the present study area.

#### *Stratigraphic range in the Sundays River Formation*

Confined to Biozones VII to I, Late Hauterivian, and to outermost shelf environments of the Sundays River Formation.

*Lagena* sp. A

Fig. 51A

#### *Remarks*

A single specimen from Biozone IV, Late Hauterivian. The test shows similarities to the *Lagena* cf. *L. striatifera* Tappan described by McMillan (1980) from the Portlandian Colchester Member of the Uitenhage Trough, onshore Algoa Basin. *Lagena* sp. A possesses 20 vertically aligned ribs, rounded in cross-section and often almost flat-topped, which fade and disappear towards both the aperture and the apical point. The apical point is raised and the apertural area is slightly developed.



?*Lagena* sp.

Fig. 51B

### Remarks

A number of broken fragments, probably of a species of *Lagena*, occur in sample 11450 from the lower part of the Zoetgeneugd Cliff outcrop (Biozone Bb, Late Valanginian). The fragment illustrated shows the apertural area and the density of the costate ornamentation, this density comparable in all other fragments found. No complete specimens have been encountered, but the test appears to have been globular.

***Lagena algoaensis* sp. nov.**

Fig. 51C–J

*Lagena apiculata neocomiana* (non Bartenstein & Brand): Beer, 1970: 17, pl. 3 (fig. 4).

### Diagnosis

A species of *Lagena* characterized by an ovate test with a prominent, stout apertural neck and a variably developed apical tube, and ornamented with a granular or tuberculate, occasionally hispid, embellishment that shows considerable variation in intensity.

### Etymology

From its occurrence in the Algoa Basin.

### Material

*Holotype* (Fig. 51C). MF1386, SOEKOR negative F160.

*Paratypes* (Fig. 51D–J). MF1387 to MF1393, seven specimens, SOEKOR negatives F161, F137, F238, F685, F237, F504, and F177.

### *Stratum typicum*

Biozone Bb, Late Valanginian, Sundays River Formation.

### *Locus typicus*

Sample 11436, Coega Brick Pits outcrop.

### Description

Test ovate in outline, subglobular and unilocular in form. Aperture terminal, produced on a stout, prominent neck, which varies from being parallel-sided to gently tapering towards its termination. Aperture a circular opening. Surface of test roughened, ornamented with irregularly distributed tuberculations and granulations that show considerable variation in density over the test surface. A finer ornament of micro-rugosities is distributed between the larger structures. The apertural neck is similarly ornamented, as in the holotype, but in other examples the rugosities may be weakly aligned vertically up the neck. The apical point of the test is marked by a short tubular projection which is often damaged or completely broken away.

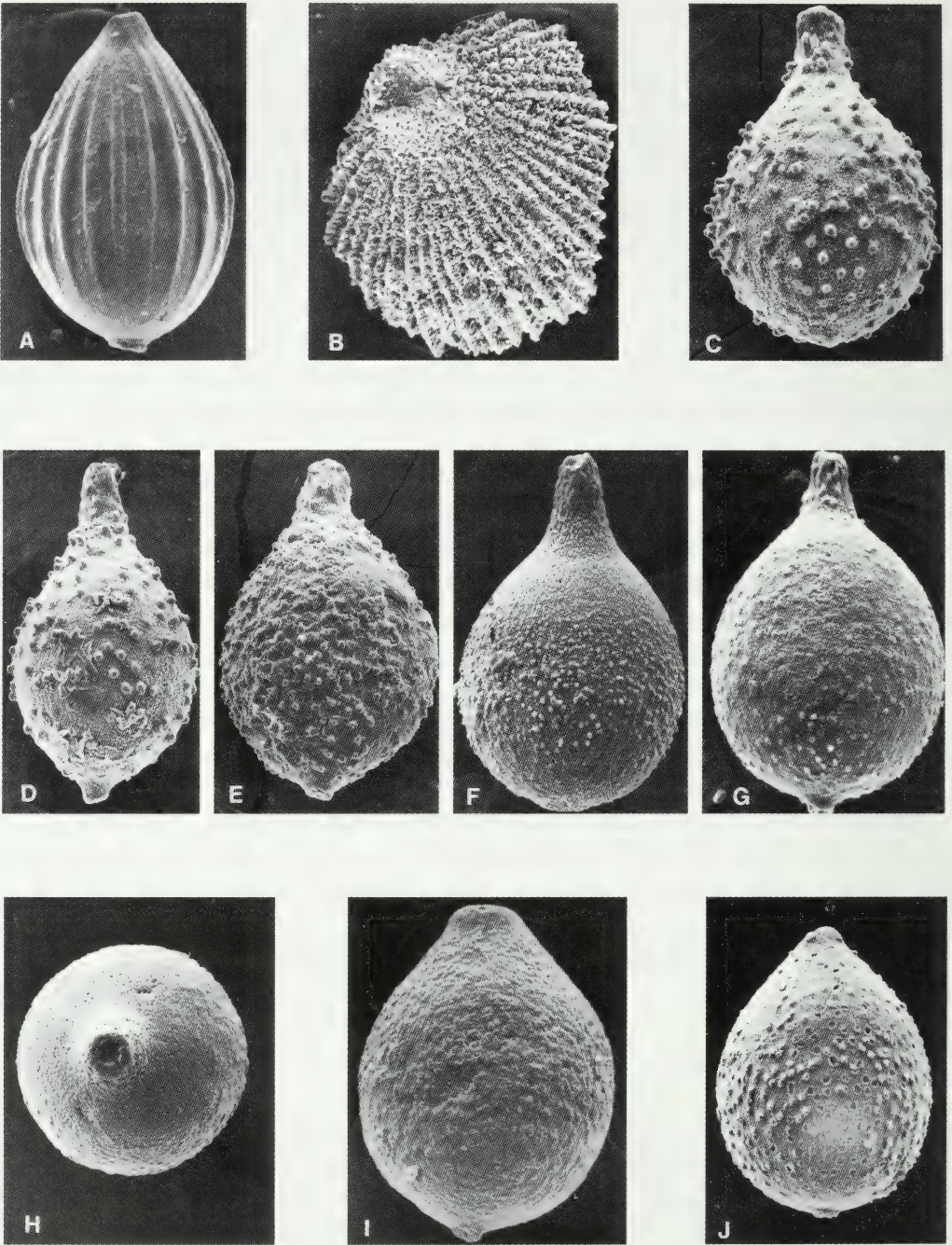


Figure 51.



### Remarks

Many *Lagena algoaensis* tests appear to be partly corroded (probably post-depositional leaching is responsible), so that the distinctive ornamentation is almost obliterated (Fig. 51I). Other tests (Fig. 51J) seem to have suffered mechanical abrasion, either through transportation of tests after death and before final deposition, or through the processing methods used on these samples. Abraded tests have had many of the tuberculations plucked out of the test surface, leaving small, irregularly shaped holes.

*Lagena algoaensis* can be clearly separated from Speeton Clay and north-west German examples of *Lagena* cf. *L. oxystoma* Reuss by its much coarser ornamentation and robust apertural neck, and by lacking the fine needle-like short spines that are parallel-sided and rounded-tipped, as figured by Bartenstein & Brand (1951, pl. 10 (fig. 331), pl. 13 (figs 354–356)). *Lagena algoaensis* differs from *L. hispida* Reuss in possessing a more elongate, pyriform test chamber, as well as lower, less well-developed spines (see Speeton Clay examples illustrated by Hart *et al.* 1981: 206, pl. 7.17 (figs 7–8)). *Lagena algoaensis* differs from *L. apiculata neocomiana* Bartenstein & Brand (1951: 317, pl. 10 (figs 275–276)) in lacking both the ‘step-like’ wide apertural neck and the dense hispid ornamentation over almost the entire exterior of the test. Examples allocated to this European species by E. M. Beer (1970) from the Sundays River Formation are regarded as referable to *L. algoaensis*. The form illustrated by Bartenstein & Bettenstaedt (1962: 255, pl. 35 (fig. 8a–b)) as *L. oxystoma* from the Late Hauterivian of north-west Germany features a more granular ornament, much in keeping with *L. algoaensis*, as here understood. Jones & Wonders (1992: 563, pl. 2 (fig. 8)) illustrated a form as *Lagena* sp. 2 from the Berriasian–Valanginian Barrow Group of offshore north-west Australia that is also very close, perhaps identical to *L. algoaensis*. *Lagena* sp. 2 again is characterized by an irregular, rather granular ornamentation, and ‘one specimen appears to possess apertures at either end’. *Lagena algoaensis* differs from the disarticulated chambers of *Nodosaria apheilolocula* Tappan, as illustrated by Tappan (1955, pl. 24 (figs 6–7)) from Early Jurassic (Late Pliensbachian) rocks of northern Alaska, in possessing a small diameter apical projection (not always preserved) that is markedly narrower, and less robustly constructed than the apertural neck. In contrast, chambers of *N. apheilolocula* display necks of much the same diameter at both ends. The ornamentation of the two species seems similar.

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Fig. 51 (see facing page). A. *Lagena* sp. A, SAM–PQ–MF1384, side view, AL 1/69, 1 390 feet (IV), F374. × 120. B. ?*Lagena* sp., SAM–PQ–MF1385, fragment of apertural area, Zoetgeneugd Cliff outcrop sample 11450 (Bb), F245. × 120. C–J. *Lagena algoaensis* sp. nov. C. Holotype, SAM–PQ–MF1386, side view, Coega Brick Pits outcrop sample 11436 (Bb), F160. × 121. D. Paratype, SAM–PQ–MF1387, side view, Coega Brick Pits outcrop sample 11436 (Bb), F161. × 102. E. Paratype, SAM–PQ–MF1388, side view, CO 1/67, 642 feet (VII), F137. × 120. F. Paratype, SAM–PQ–MF1389, side view, Zoetgeneugd Cliff outcrop sample 11450 (Bb), F238. × 200. G. Paratype, SAM–PQ–MF1390, side view, shallow borehole SB–15, core 4, 229 feet (II), F685. × 141. H. Paratype, SAM–PQ–MF1391, apertural view, Zoetgeneugd Cliff outcrop sample 11450 (Bb), F237. × 166. I. Paratype, SAM–PQ–MF1392, side view, corroded test, AL 1/69, 2 380 feet (VIII), F504. × 109. J. Paratype, SAM–PQ–MF1393, side view, abraded test, AL 1/69, 580 feet (II), F177. × 160.



Recent examination of tests of *L. apiculata neocomiana*, *L. hispida* and *Lagena* cf. *oxystoma* (as understood by Bartenstein & Brand 1951) from the Speeton Clay (Hauterivian and Barremian portion) of the Yorkshire coast indicates that South African forms previously referred to these European species must be allocated elsewhere. In particular, this includes the *L. apiculata neocomiana* of McLachlan *et al.* (1976a: 330, fig. 16 (no. 11)) from the Late Valanginian of the Mngazana Basin, and the *L. apiculata neocomiana* of McLachlan *et al.* (1976b: 356, fig. 12 (no. 27)), which is very abundant in the earliest Late Valanginian Brenton Formation and also present in the time equivalent interval of borehole PB–A1. It should be noted that this *Lagena* is confined to the Valanginian in PB–A1, and does not extend into the Hauterivian as is shown in McLachlan *et al.* (1976b, fig. 10). It is as yet unclear whether the Mngazana and the Brenton/PB–A1 examples of '*Lagena apiculata neocomiana*' are referable to the same species, since there are differences in the arrangement of the apertural neck, but it is clear this group warrants a new name.

### Occurrence

Similar forms to *Lagena algoaensis* occur in the Hauterivian of borehole PB–A1 in Pletmos Basin (discovered during re-examination of the work of McLachlan *et al.* 1976b), but in general the species is rare, usually absent in the offshore Pletmos, Gamtoos and Algoa basins in rocks of Valanginian and Hauterivian age.

### Stratigraphic range in the Sundays River Formation

Late Valanginian Biozone Bb to Late Hauterivian Biozone I, but generally rare or absent in the Early Hauterivian. The species is typical of the middle and outer shelf.

### *Lagena hauteriviana hauteriviana* Bartenstein & Brand, 1951 Figs 52A–B

*Lagena hauteriviana hauteriviana* Bartenstein & Brand, 1951: 317, pl. 10 (figs 277–278). Beer, 1970: 17, pl. 3 (fig. 5). Bettenstaedt & Spiegler, 1975: 11, pl. 2 (part), abb. 1 (figs 7–11, 19, 36–44). McLachlan *et al.*, 1976a: 330, fig. 16 (no. 12); 1976b: 356. Stapleton & Beer, 1977: 2, pl. 3 (fig. 15).

*Lagena hauteriviana* Bartenstein & Brand. Hart *et al.*, 1981: 206, pl. 7.17 (fig. 6).

### Remarks

Bettenstaedt & Spiegler (1975) examined large populations of *Lagena hauteriviana hauteriviana*, *L. apiculata apiculata* (Reuss), *L. apiculata neocomiana* Bartenstein & Brand, and *L. hauteriviana cylindracea* Bartenstein & Brand from the Early Cretaceous of north-west Germany. They concluded that all four forms are closely related, and constitute an evolutionary lineage from the Berriasian through to the Barremian. In contrast to north-west Germany and the Speeton Clay of Yorkshire, where these species are widespread, smooth-walled specimens of *Lagena* referable to this group are extremely rare in South African deposits of the same age. The difference may well be due to the

rapidity of sedimentation through the time period in South Africa, in contrast to that of the Speeton Clay and equivalent strata in north-west Germany.

The occasional smooth tests of *Lagena* in the Sundays River Formation show a variety of morphologies, some of which accord with those accepted for *L. hauteriviana* *hauteriviana* and *L. h. cylindracea*. Preservation, however, is never as good as that seen in tests from the fine-grained, shallowly buried clays of Speeton, and since complete specimens with the apertural and apical necks intact are never encountered in the Sundays River Formation, some doubt must remain as to whether the South African tests are truly referable to these European species. Since *L. h. hauteriviana* is a relatively conservative, little-ornamented form, it is difficult to establish the true relationship of these European and South African tests.

### Occurrence

*Lagena hauteriviana hauteriviana* was first described from the Late Valanginian and Hauterivian of north-west Germany (Bartenstein & Brand 1951). Later records include the Valanginian–Hauterivian boundary to the middle Barremian of north-west Germany (Bettenstaedt & Spiegler 1975); Late Berriasian (Ryazanian) to Early Barremian of the Speeton Clay, Yorkshire coast (Hart *et al.* 1981), although this difference in age perhaps results from an alternative interpretation of the species in Britain; Late Valanginian Biozone B of the Mngazana Basin, Transkei (McLachlan *et al.* 1976a); and early Late Valanginian Biozone D of both the Brenton Formation and Pletmos Basin borehole PB–A1 (McLachlan *et al.* 1976b). Similar forms to those illustrated here and by McLachlan *et al.* (1976a) occur but rarely in the Valanginian and Hauterivian rocks of the offshore Pletmos, Gamtoos and Algoa basins, South Africa.

### Stratigraphic range in the Sundays River Formation

Occasional examples occur through most of the sequence, particularly in the Late Valanginian (Biozones Bb to A) and the Late Hauterivian (Biozones VII to I). The species occurs from marginal-marine to outer-shelf locations, although it is absent in hyposaline and poorly oxygenated conditions.

*Lagena hauteriviana cylindracea* Bartenstein & Brand, 1951

Fig. 52C

*Lagena hauteriviana cylindracea* Bartenstein & Brand, 1951: 318, pl. 10 (figs 279–280).

Bettenstaedt & Spiegler, 1975: 11, pl. 2 (part), abb. 1 (figs 12–18). Bertels, 1990: 260, pl. 2 (fig. 2).

### Remarks

Only one specimen from the Sundays River Formation is sufficiently elongate to be regarded as truly referable to this subspecies. One or two intermediate forms, between subspecies *L. h. hauteriviana* and *L. h. cylindracea* occur, but these lie closer to the former, and are included therein. See the 'Remarks' for *L. h. hauteriviana*.





Figure 52.



### Occurrence

Bartenstein & Brand (1951) described *L. h. cylindracea* from the Late Hauterivian of north-west Germany; Bettenstaedt & Spiegler (1975) regarded its range as Early Hauterivian to earliest Barremian. Bertels' (1990) example is from the Hauterivian lower Río Mayer Formation of southern Argentina.

### Stratigraphic range in the Sundays River Formation

Insufficient specimens are available to determine its full range, the single true specimen being from Biozone II, Late Hauterivian.

*Lagena* spp.

Fig. 52D

### Remarks

Occasional smooth-walled specimens of *Lagena* occur that lack the apical projection of *L. h. hauteriviana* Bartenstein & Brand. These forms have, for the moment, been left in open nomenclature, as it seems of little sense to relate them to species of other ages, such as the extant *L. laevis* (Montagu). These *Lagena* spp. occur scattered throughout the Sundays River Formation sequence.

Genus *Lenticulina* Lamarck, 1804

*Lenticulina coegaensis* sp. nov.

Figs. 52E–G

*Lenticulina* (*Astacolus*) *crepidularis* (non Roemer): Beer, 1970: 12, pl. 2. (fig. 3a–b).

*Lenticulina bifurcilla* (non Bartenstein & Brand): McLachlan *et al.*, 1976a: 330, fig. 16 (no. 15); 1976b: 355, fig. 12 (no. 13).

### Diagnosis

A species of *Lenticulina* typified by a flat, strongly compressed test, a peripheral keel,

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Fig. 52 (see facing page). A–B. *Lagena hauteriviana hauteriviana* Bartenstein & Brand. A. SAM–PQ–MF1394, side view, AL 1/69, 1 270 feet (IV), F366. × 160. B. SAM–PQ–MF1395, side view, AL 1/69, 1 630 feet (VII), F444. × 120. C. *Lagena hauteriviana cylindracea* Bartenstein & Brand, SAM–PQ–MF1396, side view, AL 1/69, 610 feet (II), F181. × 137. D. *Lagena* sp., SAM–PQ–MF1397, side view, AL 1/69, 1 060 feet (III), F324. × 180. E–G. *Lenticulina coegaensis* sp. nov. E. Holotype, SAM–PQ–MF1398, side view, Coega Brick Pits outcrop sample 11988 (Bb), F150. × 109. F. Paratype, SAM–PQ–MF1399, side view, Coega Brick Pits outcrop sample 11988 (Bb), F151. × 104. G. Paratype, SAM–PQ–MF1400, side view, Uitenhage to Graaff-Reinet Road outcrop sample 11464 (Bb), F70. × 114. H. *Lenticulina* sp. A, SAM–PQ–MF1406, side view, MV 1/79, 350–360 m (Ba), F659. × 118. I. *Lenticulina 'depressosuturalis'*, SAM–PQ–MF1407, side view, offshore Gamtoos Basin, Ha–D1, 1 240–1 250 m (B: Late Valanginian), F737. × 56. J–K. *Lenticulina* cf. *L. saxonica* Bartenstein & Brand. J. SAM–PQ–MF1408, side view, AL 1/69, 1 630 feet (VII), F443. × 73. K. SAM–PQ–MF1409, side view, AL 1/69, 1 870 feet (VII), F461. × 75.

raised limbate sutural ribs bearing irregular offshoots along their length, and one or two circular ribs over the umbilicus.

### *Etymology*

Named from its frequent occurrence in the Coega Brick Pits sections.

### *Material*

*Holotype* (Fig. 52E). MF1398, SOEKOR negative F150.

*Paratypes* (Fig. 52F–G). MF1399, MF1400, SOEKOR negatives F151, and F70. MF1401 to MF1404 four additional specimens from sample 11988, Coega Brick Pits.

### *Stratum typicus*

Biozone Bb, Late Valanginian, Sundays River Formation.

### *Locus typicus*

Outcrop sample 11988, Coega Brick Pits.

### *Description*

Test strongly compressed, flat-sided, generally not lenticular. Axial periphery sub-circular to ovate, continuous. Equatorial periphery acutely angled and with a narrow-bladed keel for much of its length on the dorsal margin, and flat, rectangular on the ventral margin. Chambers arranged in an involute planispiral coil. Up to nine chambers visible externally, enlarging rather slowly and steadily in size as added. Width of chambers changes little in dimension through final whorl, but height of chambers is about three times greater in the final part of that whorl than in the initial part. Many adult tests appear to be on the verge of uncoiling but, in all examples studied, the final chamber extends back to, or very close to the umbilicus. Sutures distinct, initially evenly curved, later becoming almost straight for much of their length and strongly curved near to the test periphery: all sutures markedly backward curved. Sutures defined by raised, limbate ribs, generally rounded and broad in cross-section, but occasionally rather acute and bladed. The sutural ribs often exhibit irregular short extensions on their leading edge which develop on to the surface of the cameral wall. The number and intensity of the short extensions is variable, from one simple short rib, rapidly declining, to three or four: on the largest tests these merge into an irregular rugose pattern, and on some examples the entire central portion of each sutural rib, midway between the umbilicus and the test periphery, may become distinctly roughened. At the test margin the sutural ribs merge with the peripheral keel. Over the umbilical area the sutural ribs link with either one circular, or more usually one circular and one semicircular rib that encircle the umbilicus. Remainder of test surface smooth and unornamented in well-preserved specimens. Aperture terminal, a small circular opening surrounded by the merging of the peripheral keel and two ribs which bound the apertural face of the final chamber. Apertural face smooth, flat and unornamented, parallel-sided for most of its height in adult examples. Umbilicus narrow, often rather deep for the genus.

### Remarks

Preliminary examination of the small numbers of specimens initially available from Mngazana (McLachlan *et al.* 1976a) and borehole PB-A1 (McLachlan *et al.* 1976b) indicated that one or two short secondary ribs were developed from each sutural rib. Subsequent examination of much larger numbers of tests from the Late Valanginian of the Pletmos, Gamtoos, Algoa and Mngazana basins have shown that this is an over-simplification, and the secondary extensions of the sutural ribs may become quite complex and markedly variable, as described above. However, the single projection aligned at 30 degrees from the main sutural rib, which is seen in *Lenticulina saxonica bifurcilla* as described by Bartenstein & Brand (1951: 284, pl. 5 (fig. 114a-b)) from north-west Germany, is never seen in the South African tests.

Specimens of *Lenticulina bifurcilla* illustrated by Espitalié & Sigal (1963: 34, pl. 11 (figs 1-4)) from the ?Kimmeridgian to Hauterivian (Cenozones C to E) of the Majunga Basin are morphologically similar to north-west German examples but are rather more robustly built. That figured by Ascoli (1976) from the Berriasian-Valanginian of the East Canadian continental shelf accords even closer with the type specimens.

Juvenile specimens of *Lenticulina coegaensis* are lenticuline in outline, as is the case with the example illustrated by McLachlan *et al.* (1976a) from Mngazana, but with increasing age, the tests become flatter, with a parallel-sided apertural face to the final chamber (see Beer 1970, pl. 2 (fig. 3b)).

### Occurrence

Biozone B, Late Valanginian, Mngazana Basin (McLachlan *et al.* 1976a); Biozone B, Late Valanginian, Pletmos Basin borehole PB-A1 (McLachlan 1976b). The species appears abruptly, marking the base of Biozone B, and disappears (first down-hole appearance) equally abruptly immediately above 1At1, marking the top of Biozone B, in the offshore Pletmos, Gamtoos and Algoa basins. *Lenticulina coegaensis* is thus of considerable significance in offshore Valanginian biostratigraphy.

### Stratigraphic range in the Sundays River Formation

Base of Biozone Bb to the top of Biozone Ba (Late Valanginian). *Lenticulina coegaensis* is commonest on the middle and outer shelf, and is rare in nearshore normal marine environments, absent in hypersaline conditions.

### *Lenticulina* sp. A Figs 47L, 52H

### Remarks

Two specimens, one badly broken, characterized by deeply incised sutures and rib-like raised extensions of the chambers projecting into the umbilical area and often merging around the umbilicus. *Lenticulina* sp. A is closely related to or even the same as an ornamented, large-sized species, informally named *Lenticulina 'depressosuturalis'* (see Fig. 56I), which is characteristic of the Early to Late Valanginian (Biozones  $\gamma$  to B) of the



Pletmos, Gamtoos and Algoa basins offshore. Description of *Lenticulina* sp. A is left until the detailed taxonomy of the southern offshore Berriasian and Early Valanginian foraminifera is complete.

*Stratigraphic range in the Sundays River Formation*

*Lenticulina* sp. A is present only in the Late Valanginian Biozones Bb and Ba. The species appears to be confined to the outer shelf.

*Lenticulina* cf. *L. saxonica* Bartenstein & Brand, 1951

Figs 52J–K

see *Lenticulina (Lenticulina) saxonica saxonica* Bartenstein & Brand, 1951: 284, pl. 5 (fig. 115a–b).

see *Lenticulina saxonica* Bartenstein & Brand. Hart *et al.*, 1981: 208, pl. 7.18 (fig. 4).

*Remarks*

The few Sundays River specimens are similar in test morphology to *Lenticulina saxonica*, but there are a number of differences. Examples of *L. saxonica* for comparison have been obtained from the Hauterivian of the Speeton Clay sequence of the Yorkshire coast. Both the European and South African forms possess a peripheral, bladed keel, which is best developed in the early part of the final whorl, and which appears particularly prone to damage. The sutural ribs of the Speeton Clay examples are rather low, rounded and irregular, whereas those from the Sundays River Formation display much more massive ribs, but they are less sharply defined in relation to the adjacent chamber wall. The leading portion of each chamber in *Lenticulina* cf. *L. saxonica* is deeply indented, and rises upwards rapidly towards the posterior rib of each chamber. Such indentation does not occur on true *L. saxonica*. Hart *et al.* (1981) gave the range of *L. saxonica* as Late Valanginian to Early Barremian in Britain.

*Stratigraphic range in the Sundays River Formation*

Rare, but *Lenticulina* cf. *L. saxonica* seems to be confined to the earliest Late Hauterivian (Biozone VII), and is apparently restricted to the outermost shelf.

*Lenticulina nodosa* (Reuss, 1863) *s.l.*

Figs 53A–I, 54A–F

*Robulina nodosa* Reuss, 1863: 78, pl. 9 (fig. 6a–b).

*Lenticulina (Lenticulina) nodosa* (Reuss). Bartenstein, 1974: 540, pl. 1, pl. 2 (figs 5–6, 8–12, 16–17). Aubert & Bartenstein, 1976: 1, pl. 1 (figs 1–2, 4–13, 17–21), pl. 2 (figs 1, 3, 6–24), pl. 3 (figs 6–8), pl. 4 (figs 1, 4–8). Bartenstein & Kovatcheva, 1982: 642, pl. 3 (figs 6–7).

*Lenticulina nodosa* (Reuss). Ascoli, 1976: 686, pl. 4 (fig. 4), pl. 14 (fig. g). McLachlan *et al.*, 1976a: 331, fig. 16 (no. 18); 1976b: 355, fig. 12 (nos 18–19). Butt, 1979: 259, pl. 1 (fig. 17). Musacchio, 1979: 254, pl. 4 (fig. 7). Malumián & Nañez, 1983: 382, pl. 2 (figs 6, ?).

Kielbowicz *et al.*, 1983: 326, pl. 3 (figs 1–9). Masiuk & Viña, 1986b: 33, pl. 3 (figs 1–10), possibly pl. 1 (figs 7–10). Bertels, 1990: 264, pl. 4 (fig. 7).

*Lenticulina Lenticulina* ex gr. *nodosa* (Reuss). Crittenden, 1982: 26, pl. 1 (fig. 6).

### Remarks

Bartenstein (1974) and Aubert & Bartenstein (1976) have attempted to give order to the many forms of *Lenticulina nodosa* now known from the Austral, Tethyan and Boreal provinces. This has resulted in an increasingly complex subspeciation of the *L. nodosa* plexus, much of which does not seem especially justified. Michael (1967) and Crittenden (1982: 26) have regarded the *L. nodosa* species-group as a representing an 'iterative evolutionary modification of a smooth "lenticuline" rootstock', deriving from a species such as *Lenticulina muensteri* (Roemer). If the '*nodosa*'-type of *Lenticulina* test has developed repeatedly from smooth *Lenticulina* species (one or more) during the course of the Early Cretaceous, then it is clear that the construction of an evolutionary tree for the plexus is fraught with difficulties, and may never effectively represent the group.

Fortunately, the picture of the stratigraphic distribution of the group in South Africa is relatively simple, despite much variation, from its first appearance in the Late Berriasian to the last continuous appearance at the top of the Early Aptian. Differences exist in the intensity of the peripheral nodes, the height and intensity of limbation of the sutural ribs, the presence/absence and intensity of the umbilical boss, the number of chambers in the final whorl (and consequently the degree to which the test is lenticular or flat and almost parallel-sided in cross-section), and the extent of indentation of the test periphery between the nodes.

As discussed above (p. 140) under the 'Remarks' for the closely related *Astacolus gibber* Espitalié & Sigal, these two species have been separated simplistically in both the southern offshore basins and the Sundays River Formation in South Africa. All fully coiled tests have been referred to *L. nodosa*, whereas all tests displaying any clear uncoiling have been referred to *A. gibber*.

Two forms of *L. nodosa* have been recognized in the Sundays River Formation. The first is more common and widespread, and ranges from Biozone C, earliest Late Valanginian to Biozone I, latest Late Hauterivian. Examples of this are illustrated as Figures 53A–I and 54A–B, E–F. Rare specimens tend to become slightly evolute (Fig. 53I), but all are lenticular in cross-section (Fig. 54E–F). Tests of this form possess eight (rarely 9–10) chambers in the final whorl. The sutures may be strongly or weakly ribbed, and the peripheral nodes and the umbilical infilling vary in intensity. Differences in the degree of development of the peripheral nodes may also occur within one test (Fig. 53B).

The second form of *L. nodosa* is essentially confined to the Late Valanginian (Biozones Bb to A). The occurrence of this second form in Biozone C is not certain. Illustrated specimens are shown in Figure 54C–D. Tests are larger sized, more compressed, with the sides almost parallel when examined in apertural view. The number of chambers in the final whorl is nine or ten. These tests usually feature a rather larger umbilical infilling than is seen in the first group.

Illustrations of *L. nodosa* by McLachlan *et al.* (1976b, fig. 12 (no. 18)), from the



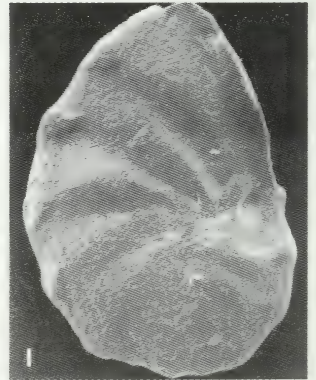
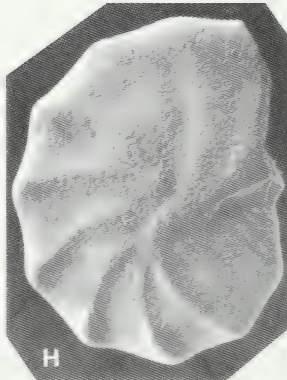
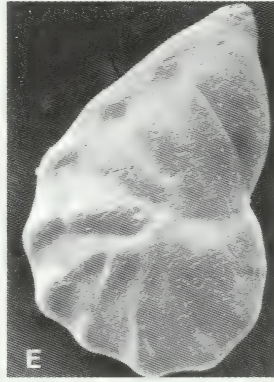
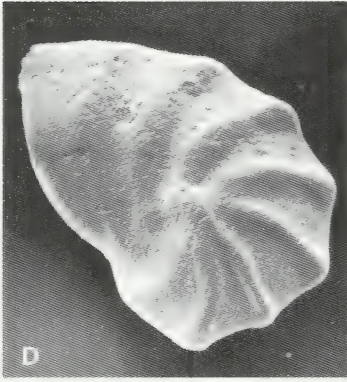
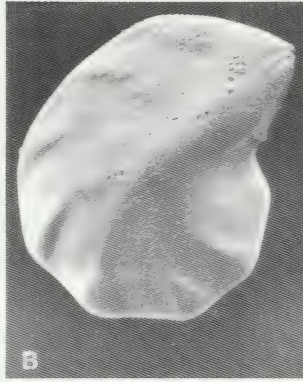


Figure 53.



earliest Late Valanginian Brenton Formation, and Biozone II, Late Hauterivian of borehole PB-A1 (fig. 12 (no. 19)) are both of the first, more common form. The illustration of *L. nodosa* by McLachlan *et al.* (1976a, fig. 16 (no. 18)) from Biozone B, Late Valanginian of the Mngazana Basin is of the second, larger-sized, Valanginian form.

In the southern offshore basins of South Africa, *L. nodosa* appears in the Late Berriasian, initially in small numbers entirely of the first form described above. From the later Early Valanginian the species becomes common, and the second form of larger-sized tests appears, to disappear later at or near the top of the Late Valanginian. In shelf environments, the first form ranges up to the top of the Hauterivian. A distinct change then occurs, and a third form of *L. nodosa* appears early in the Barremian. This group is characterized by a much more indented test periphery over each chamber, so that the nodes stand out more prominently. Extreme examples of this group may be regarded as almost spinose at the periphery; such tests are typical of the Early Aptian. The continuous occurrence of *L. nodosa* ends just below the 13At1 unconformity, high in the Early Aptian. In the Albian is a larger-sized form, with many more chambers in the final whorl, numerous peripheral nodes and a wide opaque calcite umbilical infilling, that has been referred to *L. angulosa* (Chapman). *Lenticulina angulosa* (see Chapman 1896a: 3, pl. 1 (fig. 4a–b)) has proved to be a useful down-hole marker for the top of the Albian locally in the southern offshore boreholes, and its extinction at the end of the Early Cretaceous marks the termination of the sequence of nodose *Lenticulina* in South Africa.

### Occurrence

The plexus has been regarded as ranging in the Boreal province from the Late Berriasian to the Early Hauterivian, in the Tethyan province from Kimmeridgian–Tithonian to Late Aptian, and in the Austral province from Valanginian to Aptian–Albian (Aubert & Bartenstein 1976). As discussed above, its range in South Africa is Late Berriasian to Early Aptian.

### Stratigraphic range in the Sundays River Formation

First, normal form from Biozone C to Biozone I; second, larger form from Biozone Bb to Biozone A. *Lenticulina nodosa* ranged from innermost shelf to uppermost slope and, both in the Algoa Basin and elsewhere in the southern offshore Early Cretaceous, it appears to have been one of the calcareous species most tolerant of low-oxygen conditions. It is absent in marginal-marine, hyposaline environments.

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Fig. 53 (see facing page). *Lenticulina nodosa* (Reuss) s.l. Form 1. A. SAM-PQ-MF1410, side view, AL 1/69, 310 feet (I), F31.  $\times 47$ . B. SAM-PQ-MF1411, side view, AL 1/69, 1 030 feet (III), F310.  $\times 43$ . C. SAM-PQ-MF1412, side view, AL 1/69, 1 090 feet (III), F333.  $\times 40$ . D. SAM-PQ-MF1413, side view, AL 1/69, 1 180 feet (IV), F342.  $\times 86$ . E. SAM-PQ-MF1414, side view, AL 1/69, 1 240 feet (IV), F361.  $\times 129$ . F. SAM-PQ-MF1415, side view, AL 1/69, 1 510 feet (V), F395.  $\times 82$ . G. SAM-PQ-MF1416, side view, AL 1/69, 1 600 feet (VI), F439.  $\times 76$ . H. SAM-PQ-MF1417, side view, AL 1/69, 1 870 feet (VII), F460.  $\times 40$ . I. SAM-PQ-MF1418, side view, MV 1/79, 20 m (IX), F567.  $\times 60$ .

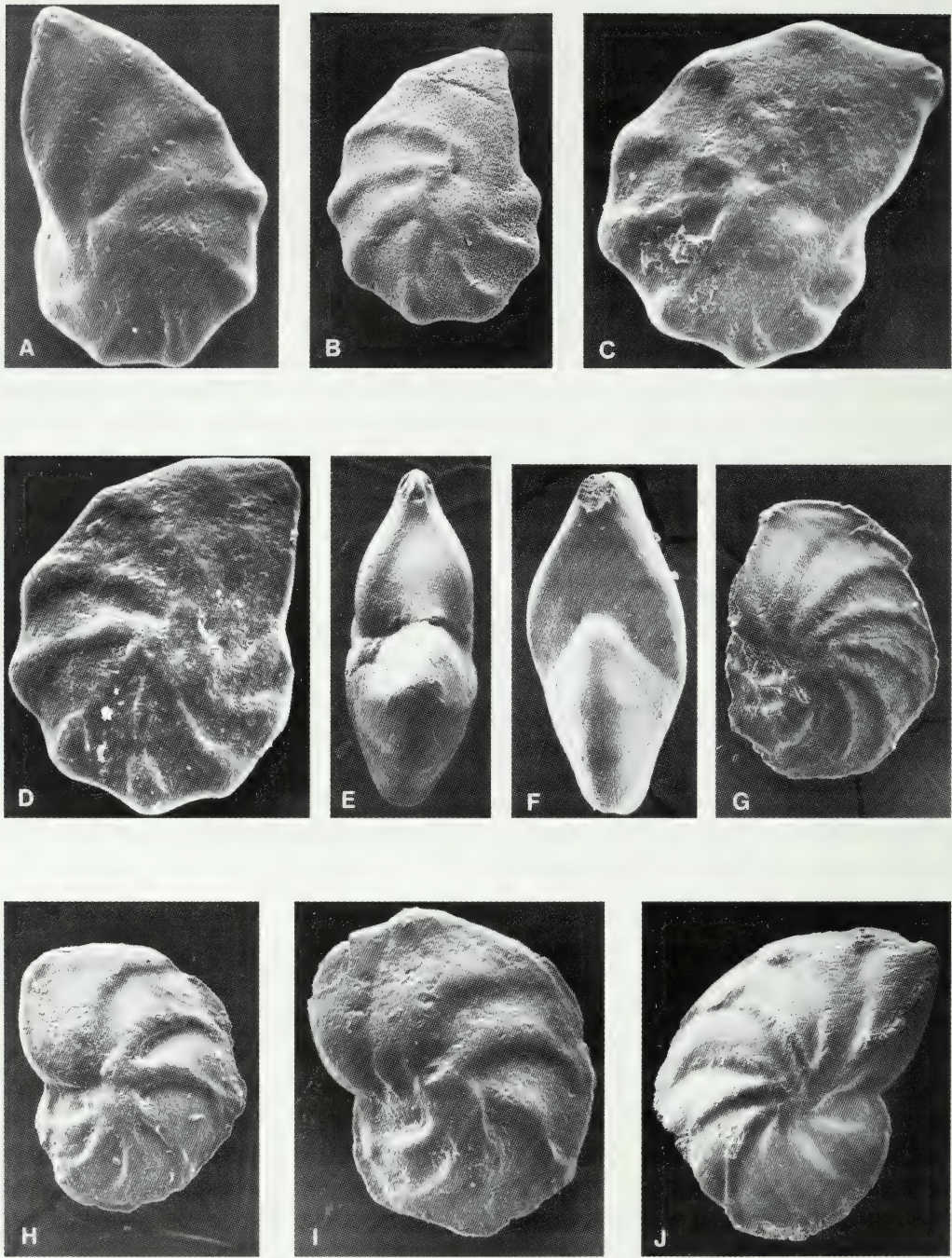


Figure 54.



*Lenticulina heiermanni* Bettenstaedt, 1952

Figs 54G–J

*Lenticulina (Lenticulina) heiermanni* Bettenstaedt, 1952: 270, pl. 1 (figs 9, 10a–b, 11a–b). Bartenstein & Bettenstaedt, 1962: 272, pl. 39 (fig. 1a–b). Bartenstein & Kaeffer, 1973: 235, pl. 6 (fig. 95).

*Lenticulina (Lenticulina) ataktos* (non Espitalié & Sigal): Beer, 1970: 12, pl. 1 (fig. 10a–b).

*Lenticulina heiermanni* Bettenstaedt. Espitalié & Sigal, 1963: 39, pl. 15 (fig. 5a–b). Butt, 1979: 259, pl. 1 (fig. 15). Hart *et al.*, 1981: 208, pl. 7.18 (fig. 1). Malumián & Nañez, 1983: 382, pl. 2 (fig. 4).

*Remarks*

The tests referred to *Lenticulina heiermanni* from the Sundays River Formation are somewhat variable, particularly in the nature of the raised sutural ribs; it may well be that more than one species is represented here. Some differences also occur in the nature of the raised mass in the umbilicus. The holotype figured by Bettenstaedt (1952, pl. 1 (fig. 11a–b)) possesses 12 chambers in the final whorl, although the largest Sundays River tests never exhibit more than ten, rarely eleven. The sutural ribs of some specimens (notably those of Fig. 54I) are distinctly broader and less sharply defined than those of the holotype. The specimen figured as *L. (L.) ataktos* Espitalié & Sigal by Beer (1970) falls within the confines of *L. heiermanni*.

*Occurrence*

Bettenstaedt (1952) and Bartenstein & Bettenstaedt (1962) gave its range in north-west Germany as latest Hauterivian to Early Aptian. Other records include: Late Hauterivian to Early Aptian in the Speeton Clay (Hart *et al.* 1981); Late Valanginian to ?Barremian (Cenozones E and F), Majunga Basin (Espitalié & Sigal 1963); and Barremian Río Mayer Formation of Santa Cruz Province, (Malumián & Nañez 1983) and Valanginian–Hauterivian Pampa Rincón Formation of Tierra del Fuego, Argentina (Malumián & Masiuk 1975). It is possible that some of the specimens illustrated as *L. muensteri* (Roemer) by Kielbowicz *et al.* (1983, pl. 2 (especially fig. 9)) from the Valanginian Springhill Formation of southern Patagonia, are referable here.

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Fig. 54 (see facing page). A–F. *Lenticulina nodosa* (Reuss) s.l. A–B, E–F. Form 1. C–D. Form 2. A. SAM–PQ–MF1419, side view, AL 1/69, 4 050 feet (A), F547. × 82. B. SAM–PQ–MF1420, side view, Coega Brick Pits outcrop sample 11436 (Bb), F159. × 48. C. SAM–PQ–MF1421, side view, MV 1/79, 410–420 m (Bb), F648. × 107. D. SAM–PQ–MF1422, side view, MV 1/79, 370–380 m (Ba), F644. × 90. E. SAM–PQ–MF1423, apertural view, AL 1/69, 520 feet (I), F192. × 80. F. SAM–PQ–MF1424, apertural view, AL 1/69, 490 feet (I), F113. × 52. G–J. *Lenticulina heiermanni* Bettenstaedt. G. SAM–PQ–MF1425, side view, AL 1/69, 520 feet (I), F117. × 41. H. SAM–PQ–MF1426, side view, AL 1/69, 580 feet (II), F168. × 68. I. SAM–PQ–MF1427, side view, AL 1/69, 2 590 feet (IX), F519. × 78. J. SAM–PQ–MF1428, side view, AL 1/69, 610 feet (II), F183. × 34.



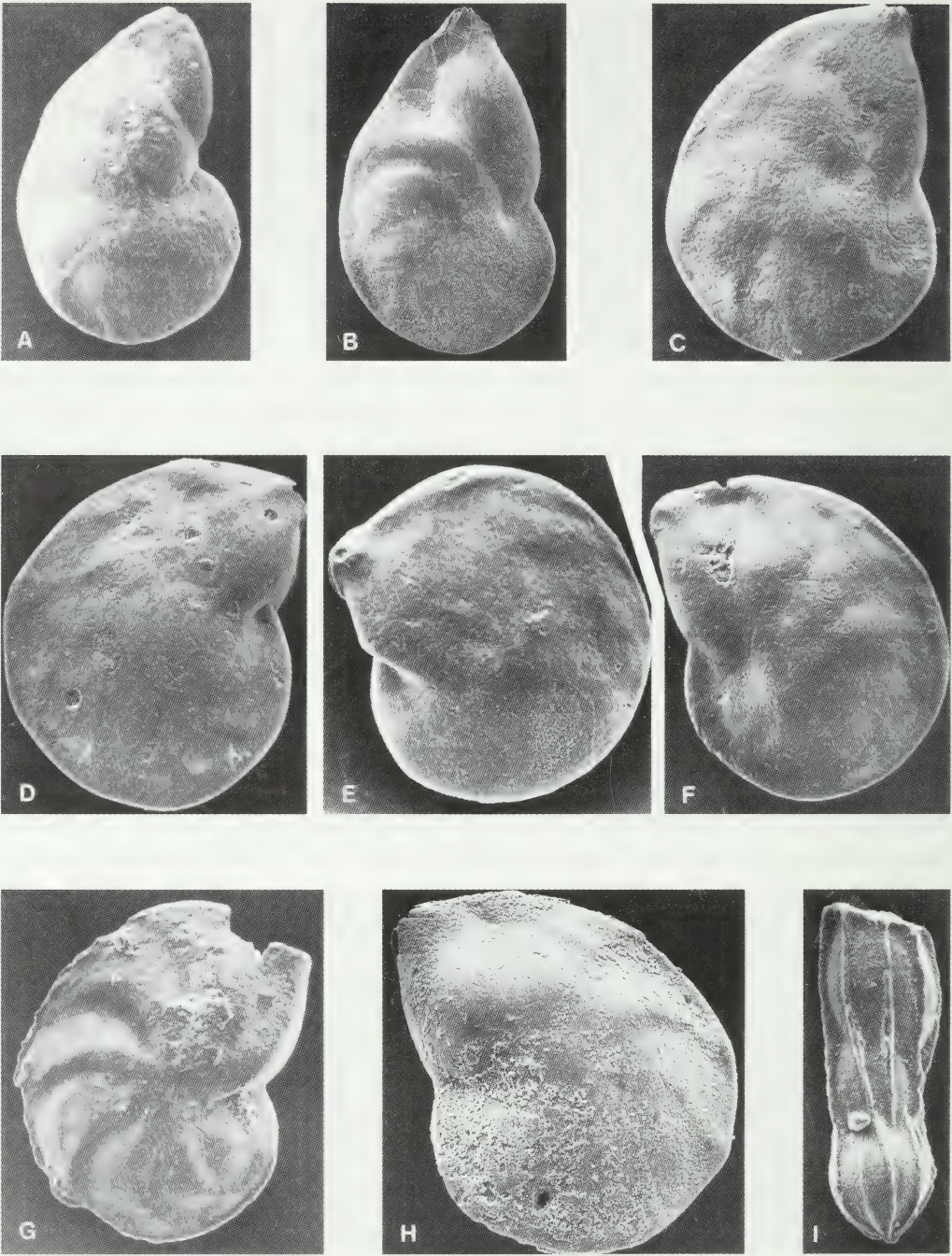


Figure 55.

*Stratigraphic range in the Sundays River Formation*

Very rare in the Early Hauterivian, and sporadic in the Late Hauterivian (Biozones IX to I).

*Lenticulina subtilis* (Wisniowski, 1890)

Figs 55A–B

*Cristellaria subtilis* Wisniowski, 1890: 226, pl. 9 (fig. 29a–b).

*Lenticulina subtilis* (Wisniowski). McLachlan *et al.*, 1976a: 331, fig. 16 (no. 16); 1976b: 355, fig. 12 (nos 14–15).

*Remarks*

Very occasional tests are referable to *Lenticulina subtilis*. All are characterized by a weakly angled periphery, sutures that are initially flush and later depressed, and the last 3–4 chambers are inflated. The specimen illustrated (Fig. 55A) is distinguished by its uncoiled final chamber. The holotype illustrated by Wisniowski (1890) possesses a rather serrate margin to the test, which is presumably a damaged keel. None of the South African forms feature a bladed keel.

*Occurrence*

First described from the Late Callovian clays of Grojek, near Krakow, Poland (Wisniowski 1890). Later records include: middle Callovian to Early Valanginian (Cenozones B to D) of the Majunga Basin (Espitalié & Sigal 1963); Late Valanginian to Hauterivian (Biozones B to III) of borehole PB–A1, Pletmos Basin (McLachlan *et al.* 1976b); and Late Valanginian (Biozone B) of the Mngazana Basin, Transkei (McLachlan *et al.* 1976a).

*Stratigraphic range in the Sundays River Formation*

Widespread, occasional examples occur from Late Valanginian Biozone C to Late Hauterivian Biozone II. The species is confined to the inner- to outer-shelf, normal marine portions of the onshore Algoa Basin.

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Fig. 55 (see facing page). A–B. *Lenticulina subtilis* (Wisniowski). A. SAM–PQ–MF1429, side view, AL 1/69, 910 feet (III), F269. × 72. B. SAM–PQ–MF1430, side view, shallow borehole SB–32, core 1, 146 feet (IV), F693. × 72. C–F. *Lenticulina muensteri* (Roemer) s.l. C. SAM–PQ–MF1431, side view, AL 1/69, 1 360 feet (IV), F369. × 84. D. SAM–PQ–MF1432, side view, shallow borehole SB–15, core 3, 212 feet (II), F679. × 90. E. SAM–PQ–MF1433, side view, MV 1/79, 140 m (X), F585. × 191. F. SAM–PQ–MF1434, side view, AL 1/69, 1 780 feet (VII), F448. × 75. G–H. *Lenticulina* cf. *L. cultrata* (Montfort). G. SAM–PQ–MF1435, side view, AL 1/69, 1 510 feet (V), F403. × 123. H. SAM–PQ–MF1436, side view, Colchester Cliff outcrop sample 12001 (IV), F714. × 116. I. *Marginulina* sp. A, SAM–PQ–MF1437, side view, shallow borehole SB–15, core 2, 210 feet (II), F674. × 130.



*Lenticulina muensteri* (Roemer, 1839) *s.l.*

Figs 55C–F

*Robulina muensteri* Roemer, 1839: 48, pl. 20 (fig. 29a–b).

*Lenticulina* (*Lenticulina*) *muensteri* (Roemer). Beer, 1970: 11, pl. 2 (fig. 1a–b).

*Lenticulina muensteri* (Roemer). Jendryka-Fuglewicz, 1975: 149, pls 8–10, pl. 11 (figs 1–6), pl. 19, pl. 20 (figs 1–2). Kielbowicz *et al.*, 1983: 325, pl. 2 (figs 7–8, 10–13, ?9). Bertels, 1990: 263, pl. 3 (fig. 14).

*Remarks*

This is the most widespread and commonest smooth-walled *Lenticulina* species in the Sundays River Formation, and is regarded as a plexus in the present work. Differences exist in the number of chambers in the final whorl (8–10), the presence or absence of slight inflation of the final few chambers of the test, the degree to which the sutures curve backwards, and the extent of the calcitic infilling of the umbilicus. An extremely detailed analysis of *L. muensteri*, using statistical methods, was provided by Jendryka-Fuglewicz (1975).

*Occurrence*

Described from the Early Cretaceous Hils Clays of northern Germany (Roemer 1839). Subsequent records of this species are exceptionally numerous and rather confused. Jendryka-Fuglewicz (1975) considered the full range of *L. muensteri* as Aalenian (Early Jurassic) to Albian in Europe. Kielbowicz *et al.* (1983) encountered the species in the Valanginian Springhill Formation, and Bertels (1990) noted it in the Hauterivian lower Río Mayer Formation of southern Argentina.

*Stratigraphic range in the Sundays River Formation*

Late Valanginian Biozone C to Late Hauterivian Biozone I, occurring in variable numbers, but commonest in the Late Hauterivian. Inner to outer shelf; absent in marginal-marine and hyposaline environments.

*Lenticulina* cf. *L. cultrata* (Montfort, 1808)

Figs 55G–H

see *Robulus cultratus* Montfort, 1808: 215, text-fig. on p. 214.

see *Lenticulina cultrata* (Montfort). Bartenstein & Brand, 1951: 281, pl. 4 (figs 101a–b, 102a–b).

*Remarks*

Variably carinate *Lenticulina* tests, with rather limbate sutures but otherwise unornamented, are particularly typical of the Late Hauterivian. For convenience they have been collected under this name. They show substantial differences in numbers of chambers per whorl, and in the style of the sutures, so that it is probable that several species are represented here.



*Stratigraphic range in the Sundays River Formation*

Early to Late Hauterivian (Biozone IX to II).

*Lenticulina* spp.*Remarks*

Specimens of smooth-walled, conservative *Lenticulina* tests that cannot be assigned to the species detailed above have not been identified to specific level, and are included here. In addition, numbers of broken or damaged *Lenticulina* tests have also been incorporated under this grouping. These occur in small numbers throughout the Sundays River Formation.

Genus *Marginulina* d'Orbigny, 1826*Marginulina* sp. A

Fig. 55I

*Remarks*

A single specimen from the Late Hauterivian Biozone II of shallow borehole SB-15. The test shows some similarity to the initial part of the *Marginulina* sp. 1 illustrated by Musacchio (1979, pl. 2 (fig. 16)) from the Callovian of Neuquén, Argentina.

*?Marginulina pyramidalis* (Koch, 1851)

Fig. 56A

see *Nodosaria pyramidalis* Koch, 1851: 169, pl. 24 (fig. 8).

see *Marginulina pyramidalis* (Koch). Bartenstein & Brand, 1951: 307, pl. 9 (figs 221–223).

Bartenstein, 1959: pl. 23 (fig. 2).

*Remarks*

One specimen of a strongly ribbed *?Marginulina* from the lowest Biozone Bb, Late Valanginian of the Zoetogeneugd Cliff outcrop. The test possesses fully rectilinear chambers throughout, but the foramen is somewhat excentric. The specimen thus has characters in common with *Nodosaria* s.l. and *Marginulina*.

Genus *Marginulinopsis* Silvestri, 1904 s.l.*Marginulinopsis parkeri* (Reuss, 1863)

Fig. 56B

*Marginulina parkeri* Reuss, 1863: 59, pl. 5 (fig. 14a–b). Chapman, 1898: 15, pl. 2 (fig. 8).

*Lenticulina* (*Marginulinopsis*) *parkeri* (Reuss). Bartenstein & Brand, 1951: 288, pl. 6 (figs 136a–b, 137a–b).

*Remarks*

The few specimens available seem best referable to Reuss's species. All specimens are

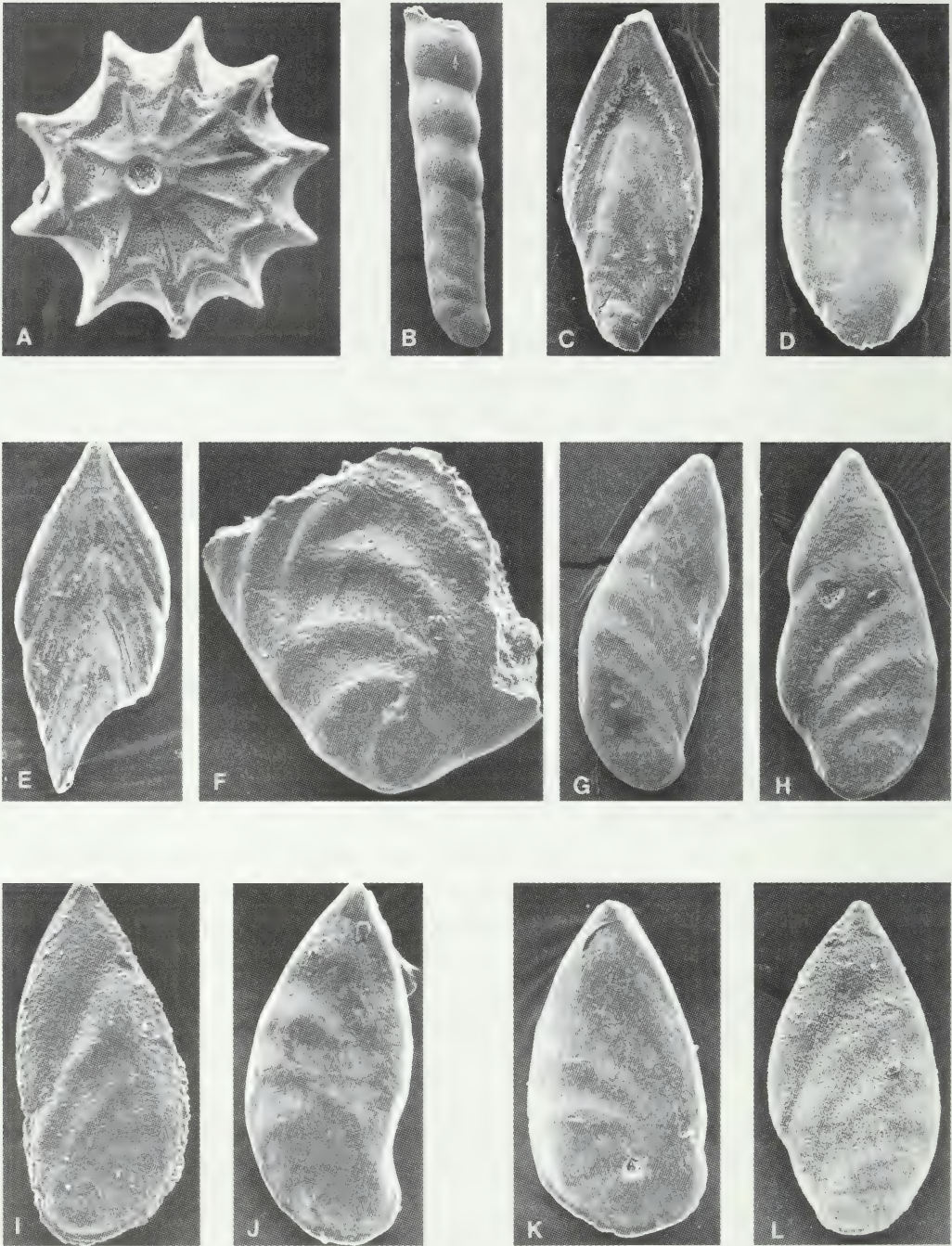


Figure 56.



slightly more compressed, the dorsal margin is less lobate in the early part of the test, and the later chambers are rather wider than high (compared to about as high as wide) than can be seen in the holotype. In the light of the generic description of *Marginulinopsis* given by Loeblich & Tappan (1988: 406), it seems likely that this species should be referred elsewhere, perhaps to *Vaginulinopsis*. Authors' earlier use has been followed in referring the species to *Marginulinopsis* s.l.

### Occurrence

Originally described from the upper Hils Clays of the Early Cretaceous of northern Germany (Reuss 1863). Bartenstein & Brand (1951) recorded the species from the middle and late Valanginian and Hauterivian of north-west Germany, and Chapman (1898) described it from the Albian Gault Clay of Southern England.

### Stratigraphic range in the Sundays River Formation

All specimens are from Shallow Borehole SB-32, probably of Biozone IV, Late Hauterivian age.

Genus *Neoflabellina* Bartenstein, 1948

*Neoflabellina* cf. *N. malakialinensis* Espitalié & Sigal, 1963

Fig. 56C-E

see *Neoflabellina* (*Falsopalmula*) *malakialinensis* Espitalié & Sigal, 1963: 56, pl. 26 (figs 7a-b, 8a-b, 9a-b).

*Neoflabellina* cf. *malakialinensis* Espitalié & Sigal. McLachlan *et al.*, 1976b: 358, fig. 12 (no. 29).

see *Palmula* cf. *malakialinensis* (Espitalié & Sigal). Malumián & Nañez, 1983: 357, pl. 1 (figs 1-6, 10-11).

### Remarks

Few specimens of *Neoflabellina* occur in the Sundays River Formation. None possess the faint surface ribs of the specimens from Mngazana (McLachlan *et al.* 1976a, fig. 16

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Fig. 56 (see facing page). A. ?*Marginulina pyramidalis* (Koch), SAM-PQ-MF1438, apertural view, Zoetogeneugd Cliff outcrop sample 11450 (Bb), F242.  $\times 112$ . B. *Marginulinopsis parkeri* (Reuss), SAM-PQ-MF1439, side view, shallow borehole SB-32, core 1, 148 feet (IV), F696.  $\times 40$ . C-E. *Neoflabellina* cf. *N. malakialinensis* Espitalié & Sigal. C. SAM-PQ-MF1440, side view, AL 1/69, 640 feet (II), F190.  $\times 82$ . D. SAM-PQ-MF1441, side view, AL 1/69, 610 feet (II), F186.  $\times 112$ . E. SAM-PQ-MF1442, side view, AL 1/69, 1 000 feet (III), F286.  $\times 48$ . F. *Palmula* sp., SAM-PQ-MF1443, side view, AL 1/69, 2 470 feet (VIII), F516.  $\times 61$ . G-L. *Planularia madagascariensis* Espitalié & Sigal s.l. G. SAM-PQ-MF1444, side view, AL 1/69, 1 630 feet (VII), F442.  $\times 61$ . H. SAM-PQ-MF1445, side view, AL 1/69, 1 180 feet (IV), F341.  $\times 88$ . I. SAM-PQ-MF1446, side view, shallow borehole SB-15, core 2, 210 feet (II), F678.  $\times 100$ . J. SAM-PQ-MF1447, side view, AL 1/69, 1 000 feet (III), F291.  $\times 112$ . K. SAM-PQ-MF1448, side view, AL 1/69, 1 000 feet (III), F289.  $\times 140$ . L. SAM-PQ-MF1449, side view, Zoetogeneugd Cliff outcrop sample 11450 (Bb), F239.  $\times 91$ .



(no. 20)) and from Brenton (McLachlan *et al.* 1976b, fig. 12 (no. 28)), and they are regarded as a separate species. The specimen illustrated here in Figure 56D, with its strongly overlapping and enfolding final chambers, is very reminiscent of a test illustrated by McLachlan *et al.* (1976b, fig. 12 (no. 29)) from the Brenton Formation. The degree to which the earlier chambers are embraced by the later ones varies greatly, and this perhaps signifies that more than one species has been included under the name *Neoflabellina* cf. *N. malakialinensis*. Because of the dearth of available tests, no further subdivision can be attempted. Comparison with the illustrations of *Neoflabellina malakialinensis* given by Espitalié & Sigal (1963) suggests that there is greater variation among the few Sundays River tests than among the Majunga Basin tests.

### Occurrence

First described from the ?Kimmeridgian to Early Portlandian (Cenozoone C) of the Majunga Basin (Espitalié & Sigal 1963). Similar forms are known from the Brenton Formation (Biozone D), and Biozone IV (Late Hauterivian) of PB-A1, Pletmos Basin (McLachlan *et al.* 1976b). Comparable tests also occur in the Barremian Río Mayer Formation of Santa Cruz Province, Argentina (Malumián & Nañez 1983).

### Stratigraphic range in the Sundays River Formation

Late Hauterivian Biozones III to II. It seems likely that its absence in the Late Valanginian is due to the rather lower oxygen values on the sea-floor during much of that time period.

Genus *Palmula* Lea, 1833

*Palmula* sp.

Fig. 56F

### Remarks

Two fragments were found that are clearly of a species of *Palmula* from Biozone VIII, Early Hauterivian. In each case, only the initial portion of the test is preserved, with an entire initial coil, and it is not possible to identify these specimens to species level. The fragments do not appear similar to *Palmula* sp. from the Late Hauterivian of Neuquén, Argentina (Musacchio 1979, pl. 5 (fig. 6)).

Genus *Planularia* Defrance, 1826

*Planularia madagascariensis* Espitalié & Sigal, 1963 *s.l.*

Figs 56G–L, 57A–D

*Planularia madagascariensis* Espitalié & Sigal, 1963: 28, pl. 6 (figs 8–11), pl. 34 (figs 1–15).

Kuznetsova, 1974: 676, pl. 2 (fig. 3a–b).

*Planularia* ex gr. *P. madagascariensis* Espitalié & Sigal. Malumián & Masiuk, 1975: 592, pl. 1 (figs 9, 10a–b).

*Planularia* cf. *madagascariensis* Espitalié & Sigal. Rigassi, 1970, pl. 83. McLachlan *et al.*, 1976a: 331, fig. 16 (no. 21).

*Planularia* gr. *madagascariensis* Espitalié & Sigal. McLachlan *et al.*, 1976b: 356, fig. 12 (no. 25, non no. 26).

*Planularia* sp. cf. *P. madagascariensis* Espitalié & Sigal. Musacchio, 1979: 258, pl. 5 (figs 1–2).

*Planularia madagascariensis australis* Masiuk & Viña, 1986a: 11, pl. 2 (figs 1–4, 13–16), pl. 3 (figs 5–10, 17, non 11–12).

non *Planularia madagascariensis madagascariensis* (non Espitalié & Sigal): Masiuk & Viña 1986a: 29, pl. 5 (figs 6–7).

### Remarks

Espitalié & Sigal (1963, pl. 34) considered the variation within this species sufficiently wide to warrant it being regarded as a plexus. Later authors have often been rather uncertain as to how to treat the plexus. The references given above provide an indication of the difficulty that exists in attempting to establish the limits of the species and of possible subspecies. It is considered here in the wide sense.

There is considerable variation too in the specimens of *P. madagascariensis* from the Sundays River Formation. The degree to which the later chambers extend back towards the proloculus, the extent of raised or depressed sutures, the degree to which the initial chambers are coiled (although they never attain a complete whorl), and the extent and intensity of the bladed keel along the dorsal margin all show substantial variation. None of the tests from the Sundays River Formation display the short ribs close to the dorsal margin that are seen in some examples from the Majunga Basin (Espitalié & Sigal 1963, pl. 34 (figs 1–9, 11–12)). One of these ornamented tests (pl. 34 (fig. 7)) is the designated holotype.

Masiuk & Viña (1986a) attempted to subdivide *P. madagascariensis* into two subspecies, *P. m. madagascariensis* and *P. m. australis*. The former (illustrated as pl. 6 (figs 8–11) and pl. 34 (figs 1–6, 8–9)) and the latter (as pl. 34 (figs 10–15)) of Espitalié & Sigal (1963), and complemented by illustrations of Argentinian Early Cretaceous specimens by Masiuk & Viña, serves merely to reinforce the concept emphasized by Espitalié & Sigal, that this species is a plexus. It is felt that, given the wide variety in morphology exhibited by the 19 tests illustrated by Espitalié & Sigal, the subspecies distinctions of Masiuk & Viña (1986a) are not justified, based partly as they are on features that are not typical, and partly on features that were not effectively illustrated and only briefly described by Espitalié & Sigal (1963). None of the 19 tests illustrated from the Majunga Basin display an entire initial whorl. In addition, Espitalié & Sigal (1963: 28) described the test margins, not clearly evident in any of the illustrations, as ‘bord ventral légèrement tronqué, bord dorsal pourvu d’une carène et régulièrement arqué’. For these reasons it is felt that the two tests referred by Masiuk & Viña (1986a, pl. 5 (figs 6–7)) to *P. m. madagascariensis* fall outside the realm of the original description and illustrations, and should be referred elsewhere, probably to *Astacolus*. They are characterized by a marked initial coil and by an abruptly angled, wide ventral margin. Furthermore, it invites other problems if forms with clearly different chamber arrangements are included. For this reason, the specimens illustrated by Masiuk & Viña (1986a) as pl. 3 (figs 11 and 12) must be referred elsewhere since they are well outside the concept of the original description and illustrations of Espitalié & Sigal (1963).





Figure 57.



### Occurrence

Described from the Middle Callovian to Early Valanginian (Cenozones B to D) of the Majunga Basin (Espitalié & Sigal 1963). Later records include DSDP site 261 near the Java Trench (Late Jurassic to ?Early Cretaceous) (Kuznetsova 1974); Valanginian–Hauterivian Pampa Rincón Formation, Tierra del Fuego (Malumán & Masiuk 1975); Late Hauterivian of Neuquén, Argentina (Musacchio 1979); Late Valanginian (Biozone B) Mngazana Basin, Transkei (McLachlan *et al.* 1976a); Late Valanginian to Late Hauterivian (Biozones D to II) of borehole PB–A1 in Pletmos Basin and Late Valanginian (Biozone D) Brenton Formation (McLachlan *et al.* 1976b). The species ranges from the Portlandian (McMillan 1980) to Early Barremian in the southern offshore basins of South Africa.

### Stratigraphic range in the Sundays River Formation

Late Valanginian to Late Hauterivian (Biozones C to I), never abundant, but widespread. *Planularia madagascariensis* occurs from shallow, normal marine environments to the outer shelf, but is absent in areas influenced by lowered salinities.

### *Planularia formosa* sp. nov.

Figs 57E–M

*Planularia* gr. *madagascariensis* (non Espitalié & Sigal, 1963): McLachlan *et al.*, 1976b: 356, fig. 12 (no. 26, non no. 25).

*Planularia* sp. aff. *P. complanata* (Reuss). Bertels, 1990: 273, pl. 6 (fig. 9).

### Diagnosis

A species of *Planularia* characterized by a narrow-bladed peripheral keel along the entire dorsal margin, with straight to gently curving, limbate sutural ribs that may possess rather irregular, almost rugose margins, and by up to four chambers arranged in an initial half-whorl, the later chambers arranged in a gentle arc.

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Fig. 57 (see facing page). A–D. *Planularia madagascariensis* Espitalié & Sigal *s.l.* A. SAM–PQ–MF1450, side view, AL 1/69, 1 240 feet (IV), F362. × 96. B. SAM–PQ–MF1451, side view, AL 1/69, 2 410 feet (VIII), F508. × 95. C. SAM–PQ–MF1452, side view, AL 1/69, 2 330 feet (VIII), F496. × 105. D. SAM–PQ–MF1453, ventral view, AL 1/69, 1 540 feet (VI), F405. × 84. E–M. *Planularia formosa* sp. nov. E. Paratype, SAM–PQ–MF1454, side view, Uitenhage to Graaff-Reinet Road outcrop sample 11464 (Bb), F77. × 102. F. Paratype, SAM–PQ–MF1455, side view, Zoetgeneugd Cliff outcrop sample 11452 (C), F253. × 64. G. Paratype, SAM–PQ–MF1456, side view, Uitenhage to Graaff-Reinet Road outcrop sample 11464 (Bb), F74. × 102. H. Paratype, SAM–PQ–MF1457, side view, Uitenhage to Graaff-Reinet Road outcrop sample 11464 (Bb), F72. × 126. I. Holotype, SAM–PQ–MF1458, side view, Coega Brick Pits outcrop sample 11988 (Bb), F152. × 63. J. Paratype, SAM–PQ–MF1459, side view, AL 1/69, 430 feet (I), F59. × 69. K. Paratype, SAM–PQ–MF1460, side view, AL 1/69, 2 030 feet (VII), F485. × 88. L. Paratype, SAM–PQ–MF1461, side view, AL 1/69, 1 630 feet (VII), F441. × 76. M. Paratype, SAM–PQ–MF1462, ventral view, AL 1/69, 520 feet (I), F195. × 88. N. *Planularia* sp. C, SAM–PQ–MF1466, side view, MV 1/79, 20 m (IX), F566. × 48.

### *Etymology*

Adjective, named for its first occurrence in PB-A1 borehole, just off Plettenberg Bay, an early Portuguese name for which was Bahia Formosa.

### *Material*

*Holotype* (Fig. 57I). MF1458, SOEKOR negative F152.

*Paratypes* (Fig. 57E–H, J–M). MF1454 to MF1457, MF1459 to MF1462, eight specimens, SOEKOR negatives F77, F253, F74, F72, F59, F485, F441, and F195.

### *Stratum typicum*

Biozone Bb, Late Valanginian, Sundays River Formation.

### *Locus typicus*

Outcrop sample 11988, Coega Brick Pits.

### *Description*

Test strongly compressed, flat-sided. Equatorial periphery acutely angled, with a narrow-bladed keel along the entire dorsal margin, and sub-rounded, flattened on the ventral margin. Axial periphery sub-circular to elongate, with dorsal margin continuous, occasionally weakly lobate in the final part of the test, and ventral margin varying from irregular to lobate in outline. Chambers arranged in an initial half-whorl of up to four, followed by an arcuate sequence of up to eight. The degree to which the later chambers extend back towards the proloculus is very variable. Later chambers about five times as wide as high. Early chambers increase rapidly in width but less rapidly in height as added, but in later chambers the increase is much less. Sutures generally distinct, raised, limbate, varying from gently curved to almost curved, rarely straight, and tending to be a little more curved close to the dorsal margin. Sutures ornamented with thick, low ribs that often exhibit sharply defined but roughened, irregular margins; ribs low, flat and wide in cross-section, although often rather rounded, perhaps through post-mortem abrasion. Sutural ribs may merge with either or both the dorsal keel or the ventral margin or, more usually, fade in intensity and almost disappear close to the dorsal and ventral margins. Occasional specimens exhibit short, sharply defined, vertically aligned ribs close to the dorsal margin, which often extend from one sutural rib vertically to the dorsal margin of the next. In rare specimens with a rather more complete initial coil, a small, irregularly shaped swelling is formed over the umbilicus. Aperture terminal, located close to the dorsal margin of the test; a circular opening that may show a faintly radiate margin. Apertural face of the final chamber narrow and parallel-sided. Surface of test smooth, apart from the ornamentation along the sutures and close to the dorsal margin.

### *Remarks*

Substantial variation is evident in the specimens assigned to *Planularia formosa*, but they can easily be separated from tests of *P. madagascariensis* Espitalié & Sigal by their distinctive surface ornamentation.

*Planularia formosa* is morphologically close to *P. complanata complanata* (Reuss), which has been described by a number of authors from the Albian of Europe: Reuss (1863), Chapman (1894*b*), Noth (1951) and Magniez-Jannin (1975). Magniez-Jannin (1975: 154, pl. 9 (figs ?31, 32–36), text-figs 83c–d)) recognized *P. c. complanata* as the least ornamented of four subspecies of Reuss's species. *Planularia c. complanata* is characterized by an initial coil of 6–7 chambers, almost of one whorl, forming one-quarter of the total height of the shell, a non-carinate dorsal margin, the later chambers always extend substantially far back towards the proloculus, and the surface ornamentation consists of fine and irregular granulations, with thin parallel ribs often close to the dorsal margin of the test; none of these features are evident in shells of *P. formosa*.

The specimen figured by Bertels (1990, pl. 6 (fig. 8)), under the name *Planularia* sp. aff. *P. complanata* (Reuss) from southern Argentina, appears to fall within the confines of *P. formosa*. Its sutures are raised and limbate, but less strongly defined than the sutures of well-preserved tests from the Sundays River Formation.

### Occurrence

Late Valanginian to Hauterivian (Biozones C to II) of PB–A1 borehole, Pletmos Basin (McLachlan *et al.* 1976*b*, and supplementary data). The species is present in small numbers in the offshore Pletmos, Gamtoos and Algoa basins in rocks of Valanginian and Hauterivian age. Also present in the Hauterivian of the lower Río Mayer Formation, southern Argentina (Bertels 1990).

### Stratigraphic range in the Sundays River Formation

Widespread, but never common from the Late Valanginian Biozone C to Late Hauterivian Biozone I. Early Hauterivian occurrences are rare.

*Planularia* sp. A  
Fig. 58A

### Remarks

A single specimen of *Planularia* from borehole AL 1/69, Biozone III, Late Hauterivian. The initial part of the test consists of a coil of four chambers in three-quarters of a whorl. The ventral margin is narrow, parallel-sided, and weakly convex to flat. The dorsal margin is ornamented with a narrow-bladed keel. Sutures are strongly ornamented with thickened ribs that are sharply defined, and rounded in cross-section. Close to the dorsal margin, the ribs abruptly thin and change direction, to reach the dorsal keel close to the dorsal end of the following suture. The thin vertical sub-dorsal ribs are almost blade-like, and decline in height towards the dorsal keel. At the point of the change in angle of the ribs, a low rounded swelling of the test extends straight along the remainder of each suture to the dorsal margin.

These ornamentation features are a re-organization of the surface characters of *P. formosa* sp. nov., described above. It is distinguished from that species, however, by the more intense ornament, and the rather rectangular cross-section of the test, although



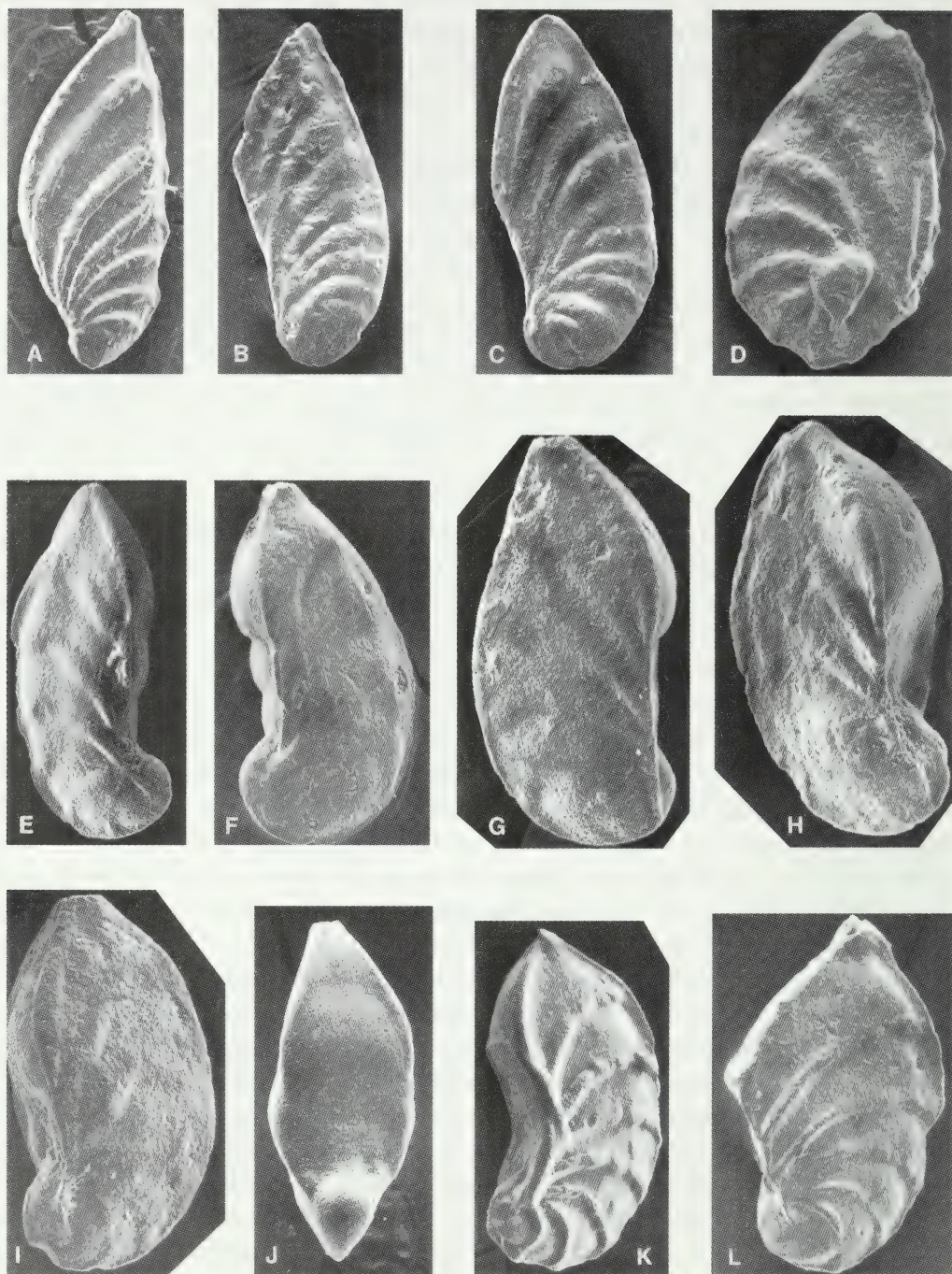


Figure 58.

the two are evidently closely related. The specimen is also similar to *Vaginulina* (*Citharina*) sp. 2376 Espitalié & Sigal (1963: 51, pl. 22 (fig. 14)) from the Hauterivian–?Barremian Cenozoone F of the Majunga Basin, but it differs in the carinate dorsal margin and the surface ornamentation close to the dorsal margin.

*Planularia* sp. B

Figs 58B–C

*Remarks*

Elongate tests that fall somewhere between *Planularia*, *Vaginulinopsis*, and even *Astacolus* are referred to the first of these genera for convenience. *Planularia* sp. B occurs very occasionally in Biozone X, Early Hauterivian. Tests are compressed, elongate-ovate in cross-section, with rounded to sub-rounded ventral margins and sub-rounded to acute dorsal margins. A very weak keel may occur on the dorsal margin in the early part of the test. The sutures are marked by raised, thick, low and rounded ribs that are at their thickest near the dorsal margin and taper steadily towards the ventral. The sutural ribs do not usually link with either the ventral or dorsal margin. These tests may prove to be related to the *Astacolus explicatus* shell illustrated by McLachlan *et al.* (1976b, fig. 11 (nos 20–21)) (*non* Espitalié & Sigal), as previously discussed in the ‘Remarks’ for that species. However, *Planularia* sp. B tests are more compressed and wider, and lack the distinctive flange of the dorsal margin of that shell.

*Planularia* sp. C

Fig. 57N

*Remarks*

A single specimen from Biozone IX, Early Hauterivian. Test compressed, elongate and parallel-sided in cross-section. Ventral and dorsal margins rounded. Sutures indistinct, initially flush, later lightly depressed. Surface of test smooth.

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Fig. 58 (*see facing page*). A. *Planularia* sp. A, SAM-PQ-MF1463, side view, AL 1/69, 1 090 feet (III), F325. × 77. B–C. *Planularia* sp. B. B. SAM-PQ-MF1464, side view, MV 1/79, 90 m, (X), F579. × 64. C. SAM-PQ-MF1465, side view, MV 1/79, 90 m, (X), F578. × 68. D. *Planularia* sp., SAM-PQ-MF1467, side view, AL 1/69, 2 030 feet (VII), F484. × 110. E–J. *Pravoslavlevia frankei* (Ten Dam). E. SAM-PQ-MF1468, side view, AL 1/69, 1 180 feet (IV), F320. × 88. F. SAM-PQ-MF1469, side view, AL 1/69, 1 570 feet (VI), F430. × 127. G. SAM-PQ-MF1470, side view, shallow borehole SB-15, core 2, 210 feet (II), F676. × 117. H. SAM-PQ-MF1471, oblique side view, AL 1/69, 2 680 feet (IX), F521. × 121. I. SAM-PQ-MF1472, side view, AL 1/69, 1 540 feet (VI), F413. × 97. J. SAM-PQ-MF1473, ventral view, AL 1/69, 520 feet (I), F130. × 43. K–L. *Pravoslavlevia pravoslavlevi* (Fursenko & Polenova). K. SAM-PQ-MF1474, side view, AL 1/69, 1 480 feet (IV), F378. × 36. L. SAM-PQ-MF1475, side view, AL 1/69, 1 870 feet (VII), F458. × 49.



*Planularia* spp.

Fig. 58D

*Remarks*

Scattered specimens of damaged or otherwise indeterminate *Planularia* tests occur; one example is figured that may be related to the example of *Planularia formosa* sp. nov. illustrated in Figure 63L. None of these specimens have proved to be of stratigraphic value.

Genus *Pravoslavlevia* Putrya, 1970*Pravoslavlevia frankei* (Ten Dam, 1946)

Figs 58E–J

*Saracenaria frankei* Ten Dam, 1946: 573, pl. 88 (fig. 1a–b).

*Lenticulina* (*Saracenaria*) cf. *italica* (non DeFrance): Bartenstein & Brand, 1951: 291, pl. 6 (fig. 149a–b). Beer, 1970: 15, pl. 2 (fig. 12a–b).

*Lenticulina* (*Saracenaria*) *frankei* Ten Dam. Noth, 1951: 47, pl. 1 (fig. 31). Bartenstein *et al.*, 1957: 33, pl. 3 (fig. 60a–b). Bartenstein & Kovatcheva, 1982: 644, pl. 3 (fig. 19).

*Saracenaria tsaramandrosoensis* (non Espitalié & Sigal): Malumián & Masiuk, 1975: 592, pl. 2 (fig. 10). McLachlan *et al.*, 1976b: 355, fig. 12 (nos 16–17). Musacchio, 1978: 151, pl. 2 (fig. 21); 1979: 258, pl. 5 (fig. 4); 1981: pl. 1 (fig. 5). Kielbowicz *et al.*, 1983: 332, pl. 4 (fig. 9).

Masiuk & Viña, 1986a: 31, pl. 6 (figs 1–2).

*Saracenaria compacta* (non Espitalié & Sigal): McLachlan *et al.*, 1976a: 331, fig. 16 (no. 22).

*Remarks*

*Pravoslavlevia frankei* was described as characterized by a small, but complete, initial coil that accounted for a fifth of the total height, with a sharp dorsal keel, and limbate flush to faintly depressed sutures. The species is relatively unornamented, compared with others of the genus. Although there are a number of references to '*Saracenaria tsaramandrosoensis*' from Argentina and South Africa, none of the illustrated specimens come close to the Espitalié & Sigal holotype from the Majunga Basin. All appear to be better referred to *P. frankei*, as indicated in the synonymy given above.

Espitalié & Sigal (1963) defined *P. tsaramandrosoensis* by its small size, slender test with parallel edges, and with the three triangular margins all strongly carinate. The gracile nature of the test is emphasized several times in the description, and this feature is borne out in the stereo-pair illustrations of the holotype (pl. 24 (fig. 2a–d)). The later chambers appear more backward extending than is usual for *Pravoslavlevia* and *Saracenaria* species, although this feature is not so evident in their specimen illustrated as figure 3a–b. In both the Majunga Basin specimens illustrated, the initial coil—described as containing from three to four chambers—appears to be scarcely more than three-quarters of a whorl in extent, but this aspect of the species is not mentioned in the description. The sutures are described as becoming gradually depressed towards the apertural–dorsal margin, and rather depressed on the ventral side.

None of the illustrated Argentinian and South African specimens referred to



*P. tsaramandrosoensis* in the synonymy above possess as strong keels along the two margins of the ventral side as along the dorsal margin; none possess the rather elongate, oblique chambers; none possess such a reduced initial coil; and none display the style of sutures typical of the holotype.

The only illustrated Argentinian specimen that comes close to the true morphology of *P. tsaramandrosoensis* is that illustrated by Malumián & Nañez (1983, pl. 2 (fig. 11)), although the two ventral keels appear to be weakly developed. Malumián & Nañez (1983: 380) pointed out that the illustrations of *P. tsaramandrosoensis* by Espitalié & Sigal (1963) suggest there are ribs close to or on the sutures that appear to be especially strongly developed in the initial part of the test, but there is no mention of these in the written description. It is evident from the further comments of Malumián & Nañez (1983) that a more detailed analysis of type material of *P. tsaramandrosoensis* from the Majunga Basin is necessary before its full distribution in the Southern Hemisphere can be established.

### Occurrence

*Pravoslavlevia frankei* has been widely recognized in the Barremian (Bettenstaedt 1952; Bartenstein & Kaever 1973; Bartenstein & Kovatcheva 1982), the Hauterivian (Ten Dam 1946; Noth 1951), the middle and late Valanginian (Bartenstein & Brand 1951) of Europe, and in the Barremian of Trinidad (Bartenstein *et al.* 1957). The following Southern Hemisphere records are regarded as referable to the same species: Valanginian–Hauterivian Pampa Rincón Formation, Tierra del Fuego (Malumián & Masiuk 1975), Late Hauterivian of the Agrio Formation, Neuquén (Musacchio 1978, 1979, 1981; Masiuk & Viña 1986a), and Valanginian Springhill Formation of southern Patagonia (Kielbowicz *et al.* 1983), all of Argentina; Late Valanginian Biozone B of the Mngazana Basin (McLachlan *et al.* 1976a), and Late Valanginian to Early Hauterivian (Biozone B to VIII) of borehole PB–A1, Pletmos Basin (McLachlan *et al.* 1976b) in South Africa.

### Stratigraphic range in the Sundays River Formation

Small numbers occur in the Late Valanginian and Late Hauterivian with only very rare examples from the Early Hauterivian (Biozone Bb to I). Confined to middle- and outer-shelf environments.

### *Pravoslavlevia pravoslavlevi* (Fursenko & Polenova, 1950)

Figs 58K–L, 59A–C

*Saracenaria pravoslavlevi* Fursenko & Polenova, 1950: 45, pl. 4 (figs 13–15). Espitalié & Sigal, 1963: 52, pl. 23 (figs 4a–d, 5a–d, 6a–d, 7a–b), pl. 24 (fig. 1a–b). Bielecka, 1975: 349, pl. 10 (figs 1, 2a–b, 3). Malumián & Masiuk, 1975: 591, pl. 1 (fig. 8). Kielbowicz *et al.*, 1983: 330, pl. 4 (figs 7–8). Bertels, 1990: 276, pl. 7 (figs 2–3).

### Remarks

A stoutly built *Pravoslavlevia* characterized by prominent raised sutural ribs, with a similar rib along either edge of the apertural face, and a narrow bladed keel along the

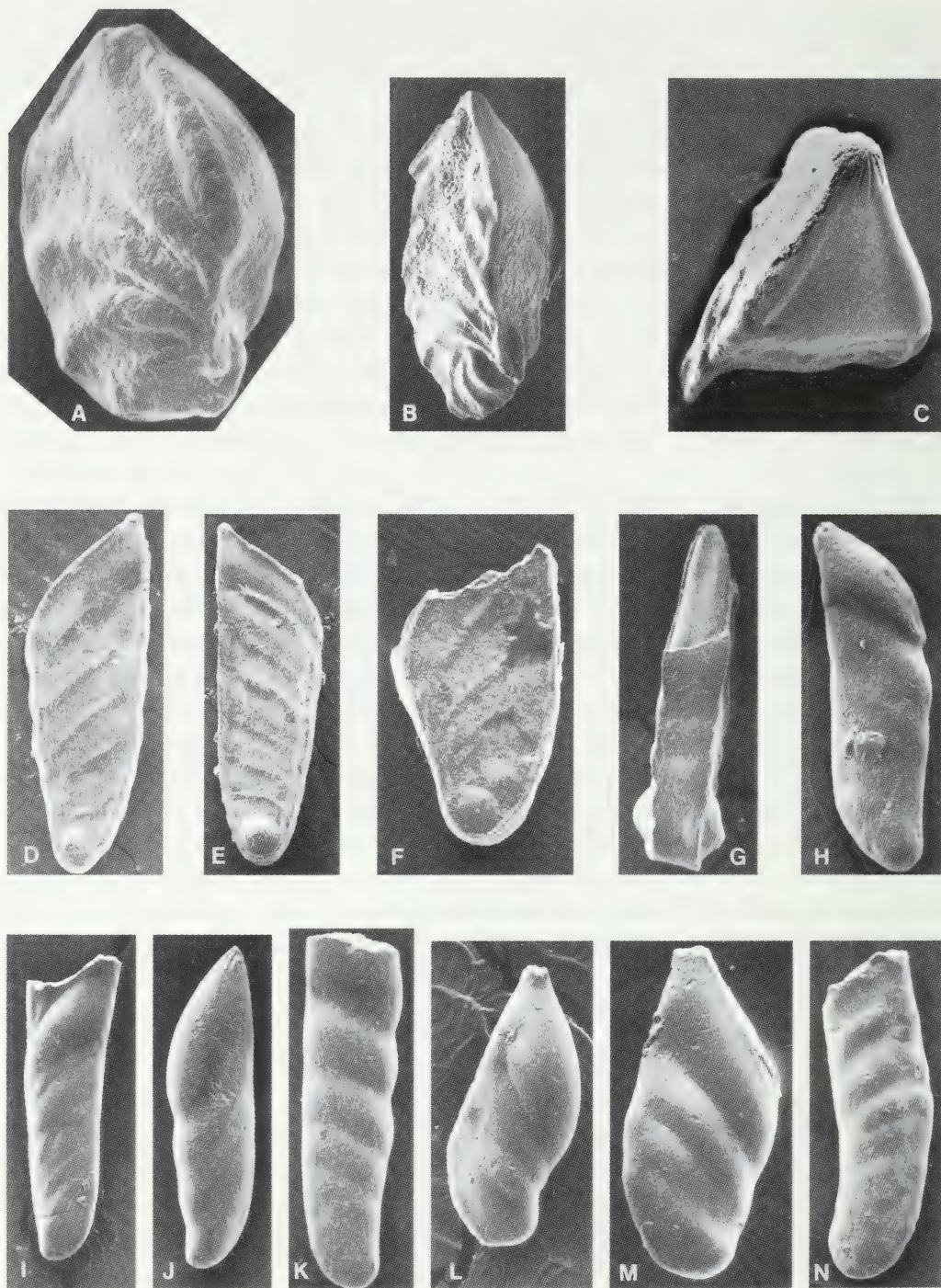


Figure 59.



dorsal margin. The ornamentation is distinctly more intense and the test is more nearly an equilateral triangle in cross-section than is seen in *P. frankei* (Ten Dam). The Sundays River Formation tests compare well with those from the Majunga Basin, Madagascar (Espitalié & Sigal 1963), and with those from Argentina (Malumián & Masiuk 1975; Kielbowicz *et al.* 1983; Bertels 1990).

Occasional examples, illustrated as Figures 58L and 59A, possess rather wider uncoiled adult parts of the test (when seen in side view) than is typical. These appear to be intermediate between *P. pravoslavlevi* and *P. compacta* (Espitalié & Sigal).

### Occurrence

Originally described from the early and middle Volgian of the Russian Platform, Russia (Fursenko & Polenova 1950). Later Southern Hemisphere records include: ?Kimmeridgian–?Barremian (Cenozones C to F) of the Majunga Basin (Espitalié & Sigal 1963), Valanginian–Hauterivian Pampa Rincón Formation of Tierra del Fuego (Malumián & Masiuk 1975), the Valanginian Springhill Formation (Kielbowicz *et al.* 1983), and the Hauterivian lower Río Mayer Formation (Bertels 1990), all of southern Argentina.

### Stratigraphic range in the Sundays River Formation

Present only in the most distal intersections studied. Very rare in the Late Valanginian (Biozone Bb), more common in the later Early and Late Hauterivian (Biozones VIII to I). Known to range up into the Early Barremian in the southern offshore basins of South Africa.

### Genus *Psilocitharella* Loeblich & Tappan, 1986

#### *Psilocitharella arguta* (Reuss, 1860)

#### Fig. 59D–G

*Vaginulina arguta* Reuss, 1860: 202, pl. 8 (fig. 4); 1863: 47, pl. 3 (fig. 13a–b). Bartenstein *et al.*, 1957: 38, pl. 5 (fig. 104), pl. 6 (fig. 136). Bartenstein *et al.*, 1971: 147, pl. 3 (fig. 58). Bartenstein & Kaeffer, 1973: 228, pl. 4 (figs 55–56). Musacchio, 1979: 254, pl. 4 (fig. 15). Hart *et al.*, 1981: 222, pl. 7.25 (figs 1–2).

Fig. 59 (see facing page). A–C. *Pravoslavlevia pravoslavlevi* (Fursenko & Polenova). A. SAM–PQ–MF1476, side view, AL 1/69, 2 410 feet (VIII), F507. × 91. B. SAM–PQ–MF1477, oblique side view, AL 1/69, 580 feet (II), F167. × 31. C. SAM–PQ–MF1478, apertural view, AL 1/69, 520 feet (I), F196. × 74. D–G. *Psilocitharella arguta* (Reuss). D. SAM–PQ–MF1479, side view, CO 1/67, 660 feet (VII), F145. × 53. E. SAM–PQ–MF1480, side view, CO 1/67, 660 feet (VII), F144. × 37. F. SAM–PQ–MF1481, side view, AL 1/69, 850 feet (III), F265. × 111. G. SAM–PQ–MF1482, edge view, AL 1/69, 1 510 feet (V), F400. × 86. H–M. *Vaginulina* spp. H. SAM–PQ–MF1483, side view, AL 1/69, 2 470 feet (VIII), F515. × 78. I. SAM–PQ–MF1484, side view, AL 1/69, 640 feet (II), F197. × 72. J. SAM–PQ–MF1485, side view, AL 1/69, 1 120 feet (III), F337. × 77. K. SAM–PQ–MF1486, side view, AL 1/69, 1 540 feet (VI), F406. × 61. L. SAM–PQ–MF1487, side view, AL 1/69, 460 feet (I), F105. × 80. M. SAM–PQ–MF1488, side view, AL 1/69, 520 feet (I), F118. × 129. N. *Vaginulinopsis* sp. A, SAM–PQ–MF1489, side view, Zoetogeneugd Cliff outcrop sample 11450 (Bb), F241. × 64.



*Vaginulina kochii* (non Roemer): Beer, 1970: 15, pl. 2 (fig. 14).

### Remarks

Test with wide, flat dorsal and ventral margins, a prominent globular proloculus that protrudes above the flat surface of the test (Fig. 59G), a peripheral rib on either side of the test that includes the proloculus, and low sutural ribs that extend for most of each straight to weakly arcuate suture. Test is rectangular in cross-section. Dorsal margin weakly convex to straight, ventral margin variably lobate, straight or faintly concave.

This is the first *Psilocitharella* to be found in the Valanginian and Hauterivian rocks of South Africa. *Psilocitharella arguta* is one of a group that have proved to be of some biostratigraphic use in the Early Cretaceous of western Europe. Kindred species are known also in the Barremian and Early Aptian of South Africa, but the group is commonest in this region in the Late Aptian to Cenomanian. However, the number of species in the group is substantially fewer in South Africa than are recognized in the Early Cretaceous of Europe. A similar situation appears to hold true for Argentina, based on published data, and it would seem that the genus *Psilocitharella* is mainly boreal in distribution.

Albers (1952) examined *Psilocitharella* assemblages in the Barremian of the Hanover region of Germany, and separated *P. kochi* (Roemer) and *P. arguta* essentially on the absence or presence, respectively, of the sutural ribs.

### Occurrence

*Psilocitharella arguta* was first described from the Albian higher Gault (Minimum clays with greensand) and ?Cenomanian of Westphalia, Germany (Reuss 1860). Later records include: upper Hils Clays (?Barremian) of northern Germany (Reuss 1863); Late Hauterivian to Middle Barremian of Heligoland (Bartenstein & Kaefer 1973); Barremian and Aptian of Bulgaria (Bartenstein *et al.* 1971); Barremian of Trinidad (Bartenstein *et al.* 1957); Early and Late Hauterivian of Neuquén, Argentina (Musacchio 1979); and base Hauterivian to Early Barremian of the Speeton Clay, England (Fletcher 1973; Hart *et al.* 1981).

### Stratigraphic range in the Sundays River Formation

Restricted to the more distal, outer-shelf localities, and confined to the Late Hauterivian (Biozones VII to II). The species is present in small, scattered numbers only.

Genus *Vaginulina* d'Orbigny, 1826

*Vaginulina* spp.

Figs 59H–M

### Remarks

Occasional examples of *Vaginulina* occur scattered through the Sundays River Formation. A wide variety of simple forms, lacking surface ornamentation, have been encountered—sufficiently wide that it is difficult to determine any species boundaries within the plexus. For the moment, no attempt has been made to separate this group into

species. *Vaginulina* spp. range from the Late Valanginian (Biozone Bb) to Late Hauterivian (Biozone I).

Genus *Vaginulinopsis* Silvestri, 1904

*Vaginulinopsis* sp. A

Fig. 59N

#### Remarks

Six specimens are referred to *Vaginulinopsis* from the lower part of the Zoetgeneugd Cliff outcrop (basal Biozone Bb, Late Valanginian). These tests possess an initial coil of well over one whorl, but otherwise are reminiscent of *Astacolus calliopsis* (Reuss).

*Vaginulinopsis* cf. *V. matutina* (d'Orbigny, 1850)

Figs 60A–C

see *Cristellaria matutina* d'Orbigny, 1850a: 242. Macfadyen, 1936: pl. 1 (fig. 264).

see *Lenticulina* (*Vaginulinopsis*) *matutina* (d'Orbigny). Bartenstein *et al.*, 1957: 31, pl. 6 (fig. 120a–b).

*Vaginulinopsis matutina* (non d'Orbigny): McLachlan *et al.* 1976b: 353, fig. 12 (nos 5–7).

#### Remarks

Although superficially similar to D'Orbigny's Liassic species, these tests exhibit distinct differences, and probably warrant a new name. The specimen of *V. matutina* from the D'Orbigny collection described by Macfadyen (1936), is characterized by a straight dorsal margin and a markedly lobate ventral margin. In cross-section this specimen is strongly compressed toward the dorsal margin, which is acute but not keeled. The ventral margin is broad and rounded. Comparison may also be made to some of the 'Form F' tests illustrated by Barnard (1960) from the English Lias.

In contrast, the South African specimens manifestly lack a lobate ventral periphery, the cross-section of the adult test is elongate-ovate, and both ventral and dorsal margins are broad and rounded, although the latter may be slightly pinched in the initial uncoiled part of the test. *Vaginulinopsis* cf. *V. matutina* is evidently closely related to the following species.

#### Occurrence

*Vaginulinopsis* cf. *V. matutina* ranges from Late Valanginian Biozone B to Late Hauterivian Biozone III in Pletmos Basin borehole PB–A1 (McLachlan *et al.* 1976b).

#### Stratigraphic range in the Sundays River Formation

Late Valanginian Biozone Bb to Late Hauterivian Biozone II, where it is rather rare, but the species is particularly abundant in the upper part of Biozone VII. This abundance in the earliest Late Hauterivian is sufficiently consistent that it can be traced across most of the boreholes intersecting this part of the section, and it has been used to define the top of Biozone VII.





Figure 60.



*Vaginulinopsis* cf. *V. prima* (d'Orbigny, 1850)  
Figs 60D–G

see *Cristellaria prima* d'Orbigny, 1850a: 242. Macfadyen, 1936: pl. 1 (fig. 266a–b).

see *Lenticulina (Vaginulinopsis) prima* (d'Orbigny). Bartenstein *et al.*, 1957: 31, pl. 3 (fig. 59a–b), pl. 4 (figs 89–90).

*Lenticulina (Vaginulinopsis) prima* (non d'Orbigny): Beer, 1970: 13, pl. 2 (fig. 10a–b).

*Vaginulinopsis* gr. *prima* (non d'Orbigny): McLachlan *et al.*, 1976b: 353, fig. 12 (nos 8–10).

### Remarks

A similar situation holds true for this species as was discussed above for *Vaginulinopsis* cf. *V. matutina* (d'Orbigny). Originally recognized from the Liassic rocks of France by D'Orbigny (1850a), more complete descriptions and the first illustrations were given by Macfadyen (1936). Macfadyen (1936: 151) described the species as: 'In section the tests appear to be flattened-lenticular; the sutures are well marked, rather broad and slightly depressed. The umbilicus of the larger specimen is excavated. The outer margin varies from being lightly keeled to sharp edged.' D'Orbigny's original (1850a) description was confined to: 'Espèce carénée, comprimée, lisse, pourvue de nombreuses loges non saillantes'.

Both the PB–A1 and Brenton examples (McLachlan *et al.* 1976b) and the present forms show marked differences from D'Orbigny's species. Particular differences exist in the broadly rounded dorsal and ventral margins of the South African tests, the flush to faintly raised sutures, the elongate-ovate cross-section in the adult part of the test, and the relatively small initial coil and long uncoiled portion in all tests studied. The Lias specimens, in contrast, display a large initial coil and a small uncoiled portion. For the moment, these South African tests have been referred to *Vaginulinopsis* cf. *V. prima*, but it seems increasingly likely that a separate name is warranted.

The distinction of *Vaginulinopsis* cf. *V. prima* from *Vaginulinopsis* cf. *V. matutina*

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Fig. 60 (see facing page). A–C. *Vaginulinopsis* cf. *V. matutina* (d'Orbigny). A. SAM–PQ–MF1490, side view, AL 1/69, 640 feet (II), F200. × 55. B. SAM–PQ–MF1491, side view, AL 1/69, 2 680 feet (IX), F520. × 54. C. SAM–PQ–MF1492, side view, AL 1/69, 1 540 feet (VI), F415. × 65. D–G. *Vaginulinopsis* cf. *V. prima* (d'Orbigny). D. SAM–PQ–MF1493, side view, CO 1/67, 642 feet (VII), F141. × 52. E. SAM–PQ–MF1494, Side view, shallow borehole SB–35, core ?, top (III), F703. × 48. F. SAM–PQ–MF1495, side view, AL 1/69, 820 feet (III), F262. × 55. G. SAM–PQ–MF1496, side view, AL 1/69, 820 feet (III), F261. × 60. H–K. *Pseudonodosaria humilis* (Roemer). H. SAM–PQ–MF1497, side view, AL 1/69, 1 000 feet (III), F295. × 73. I. SAM–PQ–MF1498, side view, AL 1/69, 400 feet (I), F52. × 69. J. SAM–PQ–MF1499, side view, AL 1/69, 340 feet (I), F40. × 85. K. SAM–PQ–MF1500, apertural view, AL 1/69, 1 060 feet (III), F318. × 160. L–N. *Lingulonodosaria nodosaria* (Reuss). L. SAM–PQ–MF1501, side view, AL 1/69, 460 feet (I), F111. × 825. M. SAM–PQ–MF1502, side view, AL 1/69, 370 feet (I), F50. × 128. N. SAM–PQ–MF1503, side view, Coega Brick Pits outcrop sample 11988 (Bb), F156. × 82. O–P. *Paralingulina hexacarinata* (Espitalié & Sigal). O. SAM–PQ–MF1504, side view, AL 1/69, 640 feet (II), F187. × 53. P. SAM–PQ–MF1504, close-up of apertural area of O, F188. × 373.

employed during the Sundays River Formation study is the same as that of McLachlan *et al.* (1976b), with the added comment that the maximum width of the uncoiled portion of the former species is adjacent to the initial coil, whereas in the latter species it is at the level of the final chamber. Nevertheless, the two are very closely related, and it may well be that they are tests from different generations of the same species.

### *Occurrence*

Late Valanginian Biozone D to Late Hauterivian Biozone III of borehole PB–A1, Pletmos Basin, and in the Late Valanginian (Biozone D) Brenton Formation (McLachlan *et al.* 1976b).

### *Stratigraphic range in the Sundays River Formation*

Rare in the Late Valanginian and Early Hauterivian, more common in the Late Hauterivian (Biozones Bb to I).

Family **Ichthyolariidae** Loeblich & Tappan, 1986

Genus *Lingulonodosaria* A. Silvestri, 1903

*Lingulonodosaria nodosaria* (Reuss, 1863)

Figs 60L–N

*Lingulina nodosaria* Reuss, 1863: 59, pl. 5 (fig. 12a–b). Magniez-Jannin, 1975: 217, text-fig. 112.

Musacchio, 1979: 258, pl. 4 (fig. 13). Malumián & Nañez, 1983: 378, pl. 1 (fig. 18).

### *Remarks*

Occasional examples of *Lingulonodosaria* occur in the Sundays River Formation. Most are as illustrated in Figure 66L–M, but scattered tests as in Figure 66N that are rather corroded seem referable here also. The height of the chambers is a little lower than in the holotype illustrated by Reuss (1863) and in the examples figured by Magniez-Jannin (1975). The aperture of the Sundays River shells is often rather damaged but, where visible, appears to be of the same dimensions as that illustrated by Reuss (1863). A number of Algoa Basin tests show signs of crushing caused by post-depositional compaction, which tends to accentuate the degree of compression of the test and the inflation of the chamber margins.

### *Occurrence*

First described by Reuss (1863) from the ‘Speeton Clay’ of northern Germany. Later records include: Gault Clay (Albian) of Folkestone (Chapman 1894a); latest Berriasian and Late Hauterivian of the Speeton Clay, Yorkshire (Fletcher 1973); Albian of the Aube region, France (Magniez-Jannin 1975); Cenomanian Grayson Formation of northern Texas (Tappan 1940); Late Hauterivian of Neuquén (Musacchio 1979) and the Barremian Río Mayer Formation, Santa Cruz Province (Malumián & Nañez 1983), both of Argentina; and Portlandian Colchester Member of the Uitenhage Trough, Algoa Basin (McMillan 1980).

*Stratigraphic range in the Sundays River Formation*

Rare in the Late Valanginian Biozones Bb and Ba, and in the Late Hauterivian Biozones VI to I.

Genus *Paralingulina* Gerke, 1969

*Paralingulina hexacarinata* (Espitalié & Sigal, 1963)

Figs 60O–P, 61A

*Frondicularia hexacarinata* Espitalié & Sigal, 1963: 60, pl. 28 (fig. 3a–b). Beer, 1973: 9. Bertels, 1990: 259, pl. 2 (fig. 19).

*Remarks*

A distinctive species of *Paralingulina* characterized by inflated, chevron-shaped chambers, a bladed peripheral keel, and two sub-peripheral sharply-defined ribs per side. The sub-peripheral ribs almost merge beneath the proloculus near the apical point of the test, and again in a distinct manner around the apertural neck. The aperture in well-preserved specimens is an elongate slit set at the top of a short, wide compressed neck. Neither Espitalié & Sigal (1963) nor Bertels (1990) provided details of the nature of the apertures of their specimens, either written or illustrated, so that their allocation of the species to *Frondicularia* cannot be confirmed without examination of their material. None the less, the distinctive test morphology is more similar to the *Paralingulina tenera* (Bornemann) plexus than to typical *Frondicularia* species. Thus, with some hesitation, the species is referred to the genus *Paralingulina*. The specimen illustrated by Bertels (1990) is rather wider than either those from the Majunga Basin (Espitalié & Sigal 1963) or the Algoa Basin (present study).

*Paralingulina tenera* is known from the European Lias (Barnard 1956; Copestake & Johnson 1981, 1989; Bartenstein & Brand 1937; Nørvang 1957) and a similar form, within the plexus, occurs as late as the Early Oxfordian in Southern Poland (Bielecka 1960). Tests of the *P. tenera* plexus in general lack inflated chambers, except perhaps for the last-formed one, the proloculus is not especially prominent, the vertical ribs usually fade away over the final chamber, and there is no well-defined apertural neck.

Bartenstein & Brand (1951: 301, pl. 8 (fig. 194a–b)) recognized *Lingulina tenera* in the Valanginian of north-west Germany, similar in all respects to the European Liassic forms. It is not possible from the descriptions and illustrations given by Bartenstein & Brand to determine if this middle to late Valanginian example can be regarded as conspecific with the Southern Hemisphere species *P. hexacarinata*, although Espitalié & Sigal (1963: 60) regarded it as 'without doubt very near, if not identical'.

*Occurrence*

Described from Biozones E and F (Late Valanginian–?Barremian) of the Majunga Basin, Madagascar (Espitalié & Sigal 1963). Bertels (1990) encountered the species in the lower Río Mayer Formation (Hauterivian) at Lago San Martín, Patagonia, Argentina.



*Stratigraphic range in the Sundays River Formation*

Restricted to the most distal parts of the Upper Sundays River Formation (Late Hauterivian Biozone III to basal Biozone I). Beer (1973) too reported it from the highest Sundays River Formation (her Biozone A). The species has not been encountered in South Africa outside the northern Algoa Basin.

Family **Lingulinidae** Loeblich & Tappan, 1961

Genus *Lingulina* d'Orbigny, 1826 *s.l.*

***Lingulina trilobita*** sp. nov.

Figs 61B–F

*Lingulina* ?*denticulocarinata* (non Chapman): McLachlan *et al.* 1976b: 358, fig. 13 (no. 5).

*Lingulina denticulocarinata* (non Chapman): Bertels, 1990: 278, pl. 7 (fig. 10).

*Diagnosis*

A species of *Lingulina* distinguished by vertically aligned indentations of the test wall close to both margins of the test, by horizontal sutures with marked downward-angled perimeters, and by a narrow, elongate slit-like aperture at the termination of a tapering, graceful test, often arthropodal in appearance.

*Etymology*

Adjective, from the morphology of the series of chambers being reminiscent of the segmental arrangement of a trilobite.

*Material*

*Holotype*. MF1506, SOEKOR negative F978 (see McLachlan *et al.* (1976b), fig. 13 (no. 5)).

*Paratypes* (Figs 61B–F). MF1507 to MF1511, five specimens, SOEKOR negatives F673, F288, F382, F309, and F329.

*Stratum typicum*

Biozone B, Late Valanginian, borehole PB–A1, Pletmos Basin.

*Locus typicus*

Borehole PB–A1, cuttings sample at 1 528 feet.

*Description*

Test compressed, elongate, with maximum width of test usually at the level of the penultimate chamber, or the base of the final one. Test graceful, tapering and, in cross-section, lenticular. Test periphery initially acutely rounded, becoming broad and rounded; in side view periphery initially straight or weakly curved, becoming a little lobate in the later part of the test. Chambers arranged in a uniserial, rectilinear sequence, increasing regularly and steadily in size as added. Initial chambers flush, last-formed

2–3 chambers weakly inflated. Chambers display marked backward-angled peripheries throughout the test; chambers initially about three times as wide as high, later slightly wider than high; up to 10 chambers in the adult test. Sutures distinct throughout, horizontal, straight, becoming strongly backward-angled towards the test periphery; initially flush, later becoming weakly depressed. Aperture terminal, centrally placed on the last-formed chamber; in form an elongate slit, very narrow, aligned parallel to the plane of compression of the test; test wall inturned, smooth and rounded around the opening. Surface of test smooth, unornamented for the most part, but with distinct, vertically aligned indentations on the lower part of each chamber, close to the test margins, developed on both sides of test. Indentations rise from the marginal change in angle of each suture, and develop for about three-quarters of the height of each chamber. In some specimens, a horizontally aligned groove or ‘double suture line’ extends just above and parallel to the true suture, around the test.

#### Remarks

McLachlan *et al.* (1976b) tentatively referred this species to *Lingulina denticulocarinata*, originally described (as *Fronicularia*) from the Albian Gault Clay of Folkestone by Chapman (1894a). Although there is some similarity in the chamber shape and suture form, *L. trilobita* lacks the distinctive thorns ranged along the test margin of Chapman’s species, and its aperture is never produced on a slight development of the final chamber. Magniez-Jannin (1975: 220, pl. 12 (fig. 17–18)) illustrated *L. denticulocarinata* from the Albian of the Aube region, France; these specimens are a little different from that figured by Chapman from Folkestone, particularly in the form of the sutures, but the peripheral thorns are well developed.

#### Occurrence

Re-examination of the PB–A1 foraminifera first described by McLachlan *et al.* (1976b) has shown that *L. trilobita* is present in Biozone B in the Late Valanginian, and in Biozones IV and III in the Late Hauterivian. The species occurs only rarely in the Late Valanginian and Hauterivian of the offshore Pletmos, Gamtoos and Algoa basins, South Africa. It also occurs in the Hauterivian lower Río Mayer Formation of southern Argentina (Bertels 1990).

#### Stratigraphic range in the Sundays River Formation

Early to Late Hauterivian (Biozones X to earliest I). It appears to avoid the oxygen-poor environments of the Late Valanginian in the Sundays River Trough. *Lingulina trilobita* ranges from the inner to outermost shelf, but avoids all marginal marine facies.



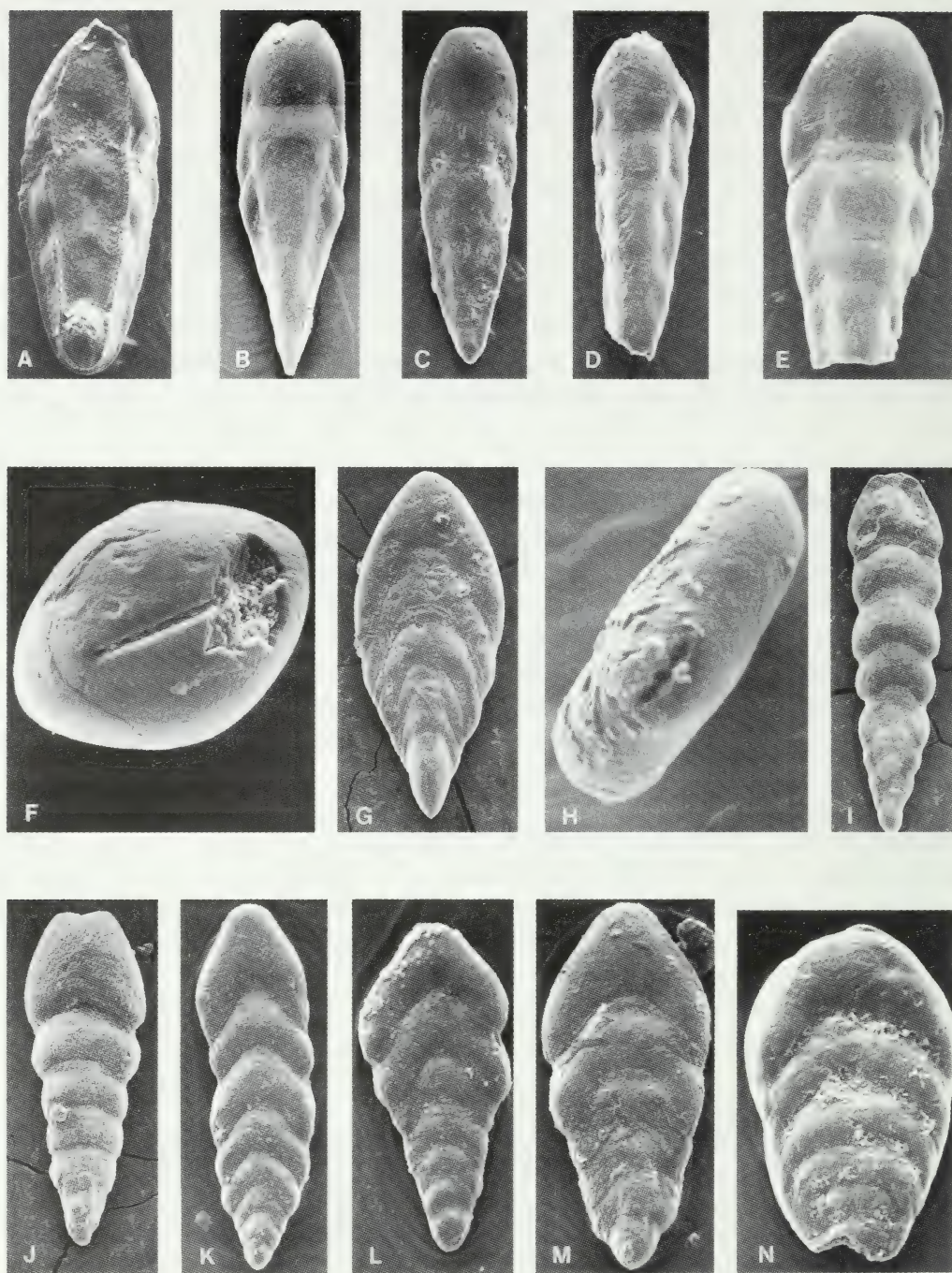


Figure 61.



*Lingulina bettenstaedti* (Zedler, 1961)

Figs 61G–H, N

*Frondicularia bettenstaedti* Zedler, 1961: 44, pl. 8 (figs 21a–b, 22a–b), text-fig. 5.

*Lingulina bettenstaedti* (Zedler). McLachlan *et al.*, 1976a: 331, fig. 16 (no. 25). Kielbowicz *et al.*, 1983: 332, pl. 2 (fig. 4).

*Remarks*

The interpretation and differentiation of this species from *Lingulina simplicissima* (Ten Dam) is based essentially on the comments and illustrations given by Zedler (1961). She separated *L. bettenstaedti* on the basis of its more numerous, lower chambers, its arched, poorly chevron-shaped chambers, and its weakly lobate test margins. The majority of the specimens referable to this species from the Sundays River Formation display rather stronger, backward-curving chambers than is typical in the north-west German tests, as shown in Figure 61G. Occasional specimens (e.g. Fig. 61N) possess rather more broadly rounded sutures, and these forms seem to be morphologically closer to the European tests.

*Occurrence*

Originally described from the Hildesiense-zone of the middle Late Hauterivian of north-west Germany (Zedler 1961); later records are sparse: Late Valanginian (Biozone B) of the Mngazana Basin (McLachlan *et al.* 1976a), and the Valanginian Springhill Formation of southern Patagonia, Argentina (Kielbowicz *et al.* 1983).

*Stratigraphic range in the Sundays River Formation*

Very occasional specimens occur in the Late Valanginian and Late Hauterivian (Biozones Ba, A, VII, III) but are insufficient to determine the full stratigraphic range.

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Fig. 61 (*see facing page*). A. *Paralingulina hexacarinata* (Espitalié & Sigal). SAM–PQ–MF1505, side view, AL 1/69, 520 feet (I), F127.  $\times 98$ . B–F. *Lingulina trilobita* sp. nov. B. Paratype, SAM–PQ–MF1507, side view, shallow borehole SB–15, core 2, 210 feet (II), F673.  $\times 110$ . C. Paratype, SAM–PQ–MF1508, side view, AL 1/69, 1 000 feet (III), F288.  $\times 112$ . D. Paratype, SAM–PQ–MF1509, side view, AL 1/69, 1 480 feet (IV), F382.  $\times 111$ . E. Paratype, SAM–PQ–MF1510, side view, AL 1/69, 1 030 feet (III), F309.  $\times 143$ . F. Paratype, SAM–PQ–MF1511, apertural view, AL 1/69, 1 090 feet (III), F329.  $\times 320$ . G–H, N. *Lingulina bettenstaedti* (Zedler). G. SAM–PQ–MF1512, side view, CO 1/67, 915 feet (VII), F149.  $\times 123$ . H. SAM–PQ–MF1513, apertural view, shallow borehole SB–9A, core 1, 282 feet 6 inches (II), F670.  $\times 430$ . N. SAM–PQ–MF1514, side view, MV 1/79, 240–250 m (A), F618.  $\times 167$ . I–K. *Lingulina praelonga* Ten Dam. I. SAM–PQ–MF1515, side view, Coega Brick Pits outcrop sample 11988 (Bb), F154.  $\times 102$ . J. SAM–PQ–MF1516, side view, Coega Brick Pits outcrop sample 11988 (Bb), F155.  $\times 121$ . K. SAM–PQ–MF1517, side view, shallow borehole SB–9A, core 1, 282 feet 6 inches (II), F668.  $\times 135$ . L–M. *Lingulina simplicissima* (Ten Dam). L. SAM–PQ–MF1518, side view, shallow borehole SB–9A, core 1, 282 feet 6 inches (II), F672.  $\times 171$ . M. SAM–PQ–MF1519, side view, shallow borehole SB–9A, core 1, 282 feet 6 inches (II), F669.  $\times 126$ .

*Lingulina praelonga* Ten Dam, 1946

Figs 61I–K

*Lingulina praelonga* Ten Dam, 1946: 576, pl. 88 (fig. 12a–b); 1948: 183. Espitalié & Sigal, 1963: 61, pl. 28 (fig. 9).

*Remarks*

A small number of specimens appear referable to Ten Dam's species, but they are distinguished by possessing rather more broadly rounded margins to the test than is typical. Tests studied exhibit up to nine chambers. The sutures are either low arched (Fig. 61I), more rounded (Fig. 61J), or more chevron-shaped (Fig. 61K). In terms of the sutural shape, the specimen in Figure 61K seems closest to Ten Dam's original illustrated specimen. The South African examples do usually feature an ovate proloculus, as noted by Ten Dam (1946).

*Occurrence*

First described from the Hauterivian of the Netherlands (Ten Dam 1946, 1948). One of the few additional records to the species is that of Espitalié & Sigal (1963), from the Late Portlandian to Early Valanginian (Cenozoone D) of the Majunga Basin, Madagascar.

*Stratigraphic range in the Sundays River Formation*

Rare examples occur in the Late Valanginian (Biozones Bb and Ba) and in the Late Hauterivian (Biozones VI to II). Because of the thin elongate test, with depressed sutures, it is probable that many specimens are damaged or destroyed in sample processing, and that broken fragments are perhaps referred to other species, particularly *L. simplicissima* (Ten Dam).

*Lingulina simplicissima* (Ten Dam, 1946)

Figs 61L–M

*Frondicularia simplicissima* Ten Dam, 1946: 576, pl. 88 (fig. 11a–b). Bartenstein, 1956: 519, pl. 2 (fig. 39). Zedler, 1961: 45, pl. 8 (figs 23a–b, 24a–b, 25a–b, 26a–b, 27a–b), text-fig. 6. Bartenstein & Kaever, 1973: 228, pl. 3 (fig. 45). Kielbowicz *et al.*, 1983: 324, pl. 2 (fig. 5). Lott *et al.*, 1986: 44, fig. 5D–E.

*Lingulina simplicissima* (Ten Dam). McLachlan *et al.*, 1976b: 358, fig. 13 (nos 3–4). Simeoni, 1985: 291, pl. 1 (figs 11–12).

*Remarks*

The specimens illustrated by Zedler (1961) from the German Hauterivian possess an elongate-ovate to slit-like aperture. Unfortunately, the original description and illustrations given by Ten Dam (1946) provide no indication (slit-like or circular) of the style of the aperture. This has led to allocations to either *Frondicularia* or *Lingulina* by various authors. Zedler's (1961) interpretation of the species has been followed here, and for this reason, it is referred to *Lingulina*. Features that distinguish *L. simplicissima* from

the similar *L. bettenstaedti* (Zedler) are the generally lobate test periphery and the distinctly chevron-shaped chambers, but gradations of these characters are evident in the Sundays River tests, indicating that the two species are very closely related.

### *Occurrence*

Widespread in the Hauterivian of north-west Europe (Ten Dam 1946, 1948; Bartenstein 1956; Bartenstein & Kaever 1973; Lott *et al.* 1986); in Argentina known from the latest Valanginian to Early Hauterivian of the Agrio Formation, Neuquén (Simeoni 1985) and the Valanginian Springhill Formation of southern Patagonia (Kielbowicz *et al.* 1983). Re-examination of the foraminifera of Pletmos Basin borehole PB-A1 (see McLachlan *et al.* 1976*b*) shows it to range from Late Valanginian Biozone B to Late Hauterivian Biozone III.

### *Stratigraphic range in the Sundays River Formation*

Occasional examples occur in the Late Valanginian Biozones Bb and Ba, and in the Late Hauterivian Biozones VII to I. The full range is certainly greater than this suggests.

### *Lingulina mngazanaensis* sp. nov.

Figs 62B–I

*Lingulina* sp. McLachlan *et al.*, 1976*a*: 333, fig. 16 (no. 26).

*Lingulina* sp. B Rieggraf, 1989: 1054, pl. 1 (fig. 12).

### *Diagnosis*

A species of *Lingulina* distinguished by rapid increase in chamber size, inflated chambers, ovate cross-section to the test, an elongate, slit-like aperture of variable length, and very weakly arched sutures.

### *Etymology*

From its first record in the Mngazana Basin of the Transkei, South Africa.

### *Material*

Holotype (Fig. 62I). MF1527, SOEKOR negative F613.

Paratypes (Figs 62B–H). MF1520 to MF1526, seven specimens, SOEKOR negatives F303, F432, F474, F681, F336, F273, and F593.

### *Stratum typicum*

Biozone X, Early Hauterivian, Sundays River Formation.

### *Locus typicus*

Borehole MV 1/79, cuttings sample 200–210 m.





Figure 62.

### Description

Test lightly compressed, elongate but rather squat, with maximum width at the level of the last-formed chamber or the penultimate one. In cross-section, test ovate, with broad rounded margins. Test periphery lobate, especially in the later part of the test. Chambers arranged in a uniserial, rectilinear sequence, increasing rapidly in size in the early part of the test, later more slowly, as added. Proloculus globular, occasionally prominent, with the following chambers flush, becoming distinctly inflated in the later part of the test. Juvenile chambers usually about twice as wide as high, later becoming about one-and-a-half times as wide as high, although significant variations occur, even in the same test; up to eight chambers in adult tests. Sutures initially flush, indistinct, later distinct, depressed, varying from almost horizontal to weakly and uniformly arched. Aperture terminal, centrally sited, orientated parallel to the plane of compression of the test; in form, an elongate narrow slit of variable length, with the test wall incurved along the margin of the opening. Surface of test smooth, unornamented.

### Remarks

Tests assigned to this species from the Sundays River Formation and the Mngazana Formation appear to constitute a plexus that cannot be easily divided. The typical form of the group is regarded as that illustrated by McLachlan *et al.* (1976a, fig. 16 (no. 26)), and as Figure 62C, E–F and I in the present study.

No previously recorded Early Cretaceous species of *Lingulina* is characterized by such a rapid increase in chamber size, by inflated chambers and by an ovate cross-section to the test. The specimen illustrated as Figure 62G shows some similarity to *Lingulina* sp. 2824 of Espitalié & Sigal (1963, pl. 28 (fig. 8)) from the Kimmeridgian to Early Portlandian (Cenozoone C) of the Majunga Basin, but this is rather atypical for *L. mngazanaensis*. There is also some similarity between *L. mngazanaensis* and *Lingulina* sp. 3 of Bartenstein & Brand (1951, pl. 8 (fig. 193a–b)), but it differs in its inflated chambers, lobate test periphery and more rapid increase in test size in the early part of the test. Some

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Fig. 62 (see facing page). A, *J. Lingulina* spp. A. SAM–PQ–MF1531, side view, AL 1/69, 520 feet (I), F124.  $\times 115$ . J. SAM–PQ–MF1532, side view, MV 1/79, 240–250 m (A), F625.  $\times 137$ . B–I. *Lingulina mngazanaensis* sp. nov. B. Paratype, SAM–PQ–MF1520, side view, AL 1/69, 1 000 feet (III), F303.  $\times 176$ . C. Paratype, SAM–PQ–MF1521, side view, AL 1/69, 1 570 feet (VI), F432.  $\times 172$ . D. Paratype, SAM–PQ–MF1522, side view, AL 1/69, 1 960 feet (VII), F474.  $\times 177$ . E. Paratype, SAM–PQ–MF1523, side view, shallow borehole SB–15, core 3, 215 feet (II), F681.  $\times 102$ . F. Paratype, SAM–PQ–MF1524, side view, AL 1/69, 1 120 feet (III), F336.  $\times 176$ . G. Paratype, SAM–PQ–MF1525, side view, AL 1/69, 940 feet (III), F273.  $\times 151$ . H. Paratype, SAM–PQ–MF1526, side view, MV 1/79, 160 m (X), F593.  $\times 175$ . I. Holotype, SAM–PQ–MF1527, side view, MV 1/79, 200–210 m (X), F613.  $\times 167$ . K. *Lingulina* sp. A, SAM–PQ–MF1528, side view, Coega Brick Pits outcrop sample 11988 (Bb), F153.  $\times 73$ . L–M. *Lingulina* cf. *L. furcillata* Berthelin. L. SAM–PQ–MF1529, side view, AL 1/69, 460 feet (I), F110.  $\times 112$ . M. SAM–PQ–MF1530, side view, shallow borehole SB–15, core 4, 229 feet (II), F687.  $\times 113$ . N–O. *Eoguttulina anglica* Cushman & Ozawa *s.l.* N. SAM–PQ–MF1533, side view, AL 1/69, 670 feet (II), F206.  $\times 123$ . O. SAM–PQ–MF1534, side view, AL 1/69, 790 feet (III), F257.  $\times 77$ .



of the shells of *L. furcillata* Berthelin illustrated by Magniez-Jannin (1975, text-fig. 113) are also close to this species, but again the South African tests develop more inflated chambers and a more lobate periphery.

### Occurrence

Late Valanginian Biozone B of the Mngazana Basin, Transkei (McLachlan *et al.* 1976a), and Barremian (not Valanginian–Hauterivian) of DSDP site 249, Mozambique Ridge, Indian Ocean (Riegraf 1989). Occasional specimens also occur in the Valanginian–Hauterivian of the offshore Gamtoos and Algoa basins, but *L. mngazanaensis* is absent in the offshore Pletmos Basin.

### Stratigraphic range in the Sundays River Formation

Late Valanginian to Late Hauterivian Biozones Bb to II. Widespread, but always rare, and only very occasional tests occur in the Early Hauterivian.

*Lingulina* sp. A

Fig. 62K

### Remarks

A single specimen from Biozone Bb, Late Valanginian of the Coega Brick Pits outcrop. It shows some similarity to the specimens incorrectly allocated to *Lingulina loryi* (Berthelin) by McLachlan *et al.* (1976b, fig. 13 (nos 1–2)), from the early Late Valanginian Brenton Formation, and probably caved from the same stratum in borehole PB–A1.

The Sundays River Formation test differs from the Brenton and PB–A1 species in its more inflated chambers and correspondingly depressed sutures. The aperture is ovate, rather intermediate between the accepted aperture outline of *Lingulina* (a slit) and of *Fronicularia* (circular).

As a supplementary note on the Brenton/PB–A1 species, it may be added here that these South African specimens are distinct from true Albian *Lingulina loryi* (see Magniez-Jannin 1975: 219, pl. 12 (fig. 16)) in their wider, more squat, and more compressed test, generally flush sutures, the occasional vertically aligned short ribs developed peripherally in the early part of the test, and the broad-bladed peripheral keel. The Brenton/PB–A1 species appears to be new, and it is hoped to formally describe it in a future re-examination of the Brenton foraminifera.

*Lingulina* cf. *L. furcillata* Berthelin, 1880

Figs 62L–M

see *Lingulina furcillata* Berthelin, 1880: 65, pl. 4 (fig. 6a–c). Said & Barakat, 1957: 43, pl. 1 (fig. 10–11).

### Remarks

Two specimens with low-arched, depressed sutures, inflated chambers, and a narrow



elongate aperture. These tests lack the backward curving peripheries to the chambers of Berthelin's illustrated test, and the sutures of the South African examples are not as strongly and evenly curved. The two illustrated tests are from Biozones II and I, later Late Hauterivian.

*Lingulina* spp.

Figs 62A, J

*Remarks*

Occasional tests of *Lingulina* that lie outside the limits of the species described above, and are poorly preserved or broken, have been allocated here. *Lingulina* tests tend to be thin-walled and particularly prone to corrosion damage induced by deterioration of pyrite infillings within chamber cavities. The specimen illustrated as Figure 62A lacks the vertically aligned peripheral indentations over the sutures that are typical of *Lingulina trilobita* sp. nov., as well as possessing more regularly arched sutures, markedly inflated chambers throughout the test and a rather wider test than is typical of that species.

Family **Polymorphinidae** d'Orbigny, 1839

Subfamily Polymorphininae d'Orbigny, 1839

Genus *Eoguttulina* Cushman & Ozawa, 1930

*Eoguttulina anglica* Cushman & Ozawa, 1930 *s.l.*

Figs 62N–O, 64A–B

*Eoguttulina anglica* Cushman & Ozawa, 1930: 16, pl. 1 (fig. 3a–c). McLachlan *et al.*, 1976a: 333, fig. 16 (no. 28). Musacchio, 1979: 258, pl. 4 (fig. 24).

*Remarks*

This is the commonest and most conservative species of *Eoguttulina* in the Late Jurassic and Early Cretaceous of South Africa. Its full range in the South African offshore basins is probably Kimmeridgian to Early Aptian. A range of morphologies is evident in the Sundays River tests but, in general, maximum test width is below mid-height, indicating rather embracing and overlapping later chambers, the chambers are moderately inflated, and the sutures correspondingly depressed and distinct for most of the test. The chambers of the holotype (Cushman & Ozawa 1930; refigured by Loeblich & Tappan 1964, fig. 415 (no. 2a–c)) are more uniformly inflated and more pyriform than those seen in the South African tests, and the initial chamber is of a distinctly larger size. Because of these differences, and because of the variation in the South African tests, it seems wisest to regard this species *sensu lato* in its usage here.

*Occurrence*

Described by Cushman & Ozawa (1930) from the Cambridge Greensand (earliest Cenomanian) of England. Subsequent records include: Hauterivian (Ten Dam 1948) and Albian (Ten Dam 1950) of the Netherlands; Albian of Romania (Neagu 1965); Kimmeridgian (Lloyd 1962) of England; Valanginian–Hauterivian Pampa Rincón

Formation (Malumián & Masiuk 1975) and Late Hauterivian of Neuquén (Musacchio 1979), Argentina; and Late Valanginian Biozone B of the Mngazana Basin, Transkei (McLachlan *et al.* 1976a).

#### *Stratigraphic range in the Sundays River Formation*

Ranges throughout the sequence, Biozone C to Biozone I. The species is often most frequent in rather poorly oxygenated environments where agglutinated foraminifera predominate and few other calcareous foraminifera occur. Its environmental range is innermost shelf to slope, but it is absent in littoral, high-energy environments and hyposaline, estuarine conditions.

*Eoguttulina* cf. *E. inovroclaviensis* (Bielecka & Pożaryski, 1954)

Figs 63A–C

see *Sigmomorphina inovroclaviensis* Bielecka & Pożaryski, 1954: 63, 192, pl. 9 (fig. 47a–c).

*Eoguttulina* cf. *inovroclaviensis* (Bielecka & Pożaryski). McLachlan *et al.*, 1976a: 333, fig. 17 (no. 1).

non *Eoguttulina* cf. *inovroclaviensis* (non Bielecka & Pożaryski) McLachlan *et al.*, 1976b: 358, fig. 13 (no. 9).

#### *Remarks*

One or two specimens compare closely to the test illustrated by McLachlan *et al.* (1976a), in their strongly lobate margins and abrupt basal terminations to the later chambers. Such differences enable them to be easily distinguished from *Eoguttulina anglica* Cushman & Ozawa s.l. The later chambers of South African *Eoguttulina* cf. *E. inovroclaviensis* are rather narrow and elongate. Because of poor preservation, the chamber arrangement of the early part of the tests is often obscured or obliterated, so that they are referred to Bielecka & Pożaryski's species with great reservations.

#### *Occurrence*

First described from the Kimmeridgian to Portlandian of Poland (Bielecka & Pożaryski 1954). Later records include Kimmeridgian of England (Lloyd 1962). The similar South African forms occur in the Late Valanginian Biozone B of the Mngazana Basin (McLachlan *et al.* 1976a). These have also been found, very rarely, in the offshore Gamtoos and Algoa basins in the Valanginian, but appear to be absent everywhere in the generally shallower-water environments of the Valanginian succession of the Pletmos Basin.

#### *Stratigraphic range in the Sundays River Formation*

Confined to the Late Hauterivian (Biozones VI to II). There are signs that the species prefers outer-shelf environments, and it is never found in shallow or marginal marine conditions, but too few specimens are available to determine its full range. In contrast, in the Colchester Member of the Uitenhage Trough, *Eoguttulina* cf. *E. inovroclaviensis* is found in shallow marine facies (McMillan 1980).

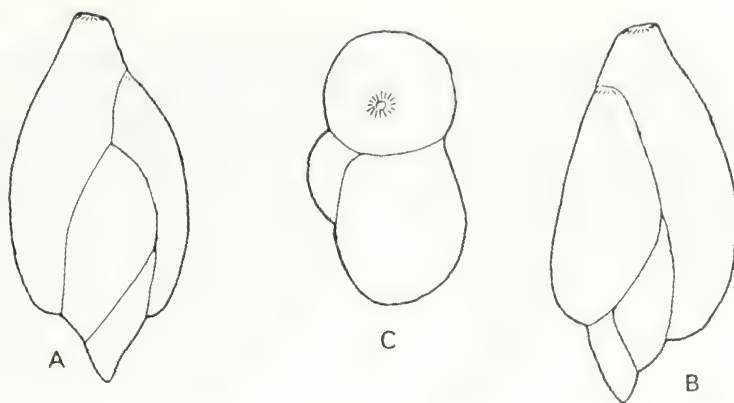


Figure 63.

*Eoguttulina* cf. *E. inovroclaviensis* (Bielecka & Pożaryski). A–B. Side views. C. Apertural view. All SAM–PQ–MF1537, AL 1/69, 940 feet, (III).  $\times 135$ .

*Eoguttulina* cf. *E. liassica* (Strickland, 1846)

Figs 64C–E

see *Polymorphina liassica* Strickland, 1846: 31, text-fig. b.

see *Eoguttulina liassica* (Strickland). Lloyd, 1962: 370, pl. 1 (figs 1a–d, 2a–c, 3a–c), text-fig. 2.

Winter, 1970: 39, pl. 4 (fig. 135).

*Eoguttulina* cf. *liassica* (Strickland). McLachlan *et al.*, 1976a: 333, fig. 16 (no. 27).

non *Eoguttulina* cf. *liassica* (Strickland): McLachlan *et al.*, 1976b: 358, fig. 13 (no. 8).

### Remarks

South African specimens from the Valanginian and Hauterivian compare closely with the more globular, megalospheric tests illustrated by Lloyd (1962) from the English Kimmeridge Clay. Lloyd has shown in detail the variation of this plexus in the Kimmeridgian, but it is clear that his interpretation of the species is wider than accepted by most authors, who have followed Strickland's (1846) original illustration more closely. Forms similar to Strickland's example are scarcely distinguishable from *Eoguttulina anglica* Cushman & Ozawa.

It is not clear whether the South African specimens are properly referable to *Eoguttulina liassica*, bearing in mind the differences in authors' interpretations of the species, so for the time being they have been referred to *Eoguttulina* cf. *E. liassica*.

### Occurrence

Widespread in the Jurassic of north-west Europe.

### Stratigraphic range in the Sundays River Formation

*Eoguttulina* cf. *E. liassica* occurs in small numbers from the Late Valanginian Biozone Bb to Late Hauterivian Biozone I.





Figure 64.

*Eoguttulina* cf. *E. polygona* (Terquem, 1864)

Figs 64F–G

see *Polymorphina polygona* Terquem, 1864: 305, pl. 14 (figs 16, 19–21, 23a–b, 35, 39).

see *Eoguttulina polygona* (Terquem). Lloyd, 1962: 372, pl. 1 (fig. 4a–c), text-fig. 3.

*Remarks*

Small numbers of tests show the elongate shell and distinctive chamber arrangement characterized by slight overlap that are typical of Jurassic *Eoguttulina polygona*. Too few tests have been obtained to permit detailed analysis of the form in the Sundays River Formation.

*Stratigraphic range in the Sundays River Formation*

Confined to the latest Valanginian and Early Hauterivian (Biozones A to IX) of the most distal borehole intersections.

*Eoguttulina* sp. B

Figs 64H–I

*Remarks*

An elongate, fusiform, large-sized species of *Eoguttulina*, with weakly depressed sutures and strongly overlapping chambers, that shows some resemblance to *Eoguttulina oolithica* (Terquem). The Algoa Basin tests differ from that species, however, in possessing rather less-overlapping chambers than is typical (see Lloyd 1962, pl. 1 (fig. 8a–c), text-fig. 5). The Sundays River Formation tests are easily distinguished from other species of the genus, initially on the size of the test and, although often crushed (Fig. 64I) or otherwise damaged, the species occurs widely enough to warrant its use as a zone marker in a part of the Sundays River sequence that is difficult to subdivide.

*Stratigraphic range in the Sundays River Formation*

Late Valanginian to Early Hauterivian (Biozones C to IX).

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Fig. 64 (see facing page). A–B. *Eoguttulina anglica* Cushman & Ozawa s.l. A. SAM–PQ–MF1535, side view, AL 1/69, 2 710 feet (IX), F522.  $\times 166$ . B. SAM–PQ–MF1536, side view, AL 1/69, 2 710 feet (IX), F523.  $\times 124$ . C–E. *Eoguttulina* cf. *E. liassica* (Strickland). C. SAM–PQ–MF1538, side view, AL 1/69, 3 450 feet (X), F538.  $\times 173$ . D. SAM–PQ–MF1539, side view, AL 1/69, 1 540 feet (VI), F418.  $\times 173$ . E. SAM–PQ–MF1540, side view, AL 1/69, 520 feet (I), F122.  $\times 160$ . F–G. *Eoguttulina* cf. *E. polygona* (Terquem). F. SAM–PQ–MF1541, side view, MV 1/79, 90 m (X), F573.  $\times 114$ . G. SAM–PQ–MF1542, side view, MV 1/79, 90 m (X), F575.  $\times 142$ . H–I. *Eoguttulina* sp. B. H. SAM–PQ–MF1543, side view, MV 1/79, 90 m (X), F580.  $\times 72$ . I. SAM–PQ–MF1544, side view, MV 1/79, 200–210 m (X), F610.  $\times 78$ . J–N. *Globulina prisca* Reuss s.l. J. SAM–PQ–MF1545, side view, Zoetogeneugd Cliff outcrop sample 11452 (C), F255.  $\times 137$ . K. SAM–PQ–MF1546, side view, AL 1/69, 1 480 feet (IV), F391.  $\times 128$ . L. SAM–PQ–MF1547, side view, AL 1/69, 490 feet (I), F115.  $\times 164$ . M. SAM–PQ–MF1548, side view, MV 1/79, 20 m (IX), F568.  $\times 140$ . N. SAM–PQ–MF1549, side view, AL 1/69, 1 480 feet (IV), F389.  $\times 148$ .



Genus *Globulina* d'Orbigny, 1839

*Globulina prisca* Reuss, 1863 *s.l.*

Figs 64J–N

*Polymorphina (Globulina) prisca* Reuss, 1863: 79, pl. 9 (fig. 8a–b).

*Globulina prisca* Reuss. Beer, 1970: 18, pl. 3 (fig. 8a–b). McLachlan *et al.*, 1976a: 333, fig. 17 (no. 2); 1976b: 358, fig. 13 (nos 6–7). Stapleton & Beer, 1977: 2, pl. 3 (fig. 14a–b). Malumián & Nañez, 1983: 379, pl. 1 (figs 19–20). Bertels, 1990: 278, pl. 7 (fig. 12).

### Remarks

Tests from South Africa possess rather broader, rounded apical ends, with maximum width of test in the lower half, than was originally illustrated by Reuss (1863). The acute apical termination of the test figured in Figure 64K is atypical.

### Occurrence

Widely reported from the Early Cretaceous. First described from the upper Hils Clays (Barremian to Early Aptian) and the Minimus Clays (Late Albian) of northern Germany (Reuss 1863). Later records include: Late Valanginian Biozone B of the Mngazana Basin, Transkei (McLachlan *et al.* 1976a), earliest Late Valanginian (Biozone D) of the Brenton Formation (McLachlan *et al.* 1976b; Stapleton & Beer 1977), and the Late Valanginian (Biozones B and A) of Pletmos Basin borehole PB–A1 (McLachlan *et al.* 1976b). The species is widespread in South Africa, ranging at least from the Portlandian to the Early Aptian.

### Stratigraphic range in the Sundays River Formation

Occurs in small, variable numbers throughout the sequence, from Biozones D to I. The species tolerates a wide range of environments, from innermost shelf to upper slope, including those with reduced oxygen conditions on the sea-floor, but is absent from hyposaline locations.

Genus *Pseudopolymorphina* Cushman & Ozawa, 1928

*Pseudopolymorphina colchesterensis* sp. nov.

Figs 65A–H

### Diagnosis

A species of *Pseudopolymorphina* distinguished by a compressed test with a broad, rounded periphery, flush to weakly depressed sutures, and a smooth, unornamented test surface.

### Etymology

From its abundance at several horizons in the Colchester Cliff outcrop, close to Colchester railway halt.



### Material

*Holotype* (Fig. 65E). SAM-1554; SOEKOR negative F350.

*Paratypes* (Fig. 65A–D, F, G/H). MF1550 to MF1553, MF1555, MF1556, six specimens, SOEKOR negatives F706, F709, F708, F705, F343, and F344/F345.

### *Stratum typicum*

Biozone IV, Late Hauterivian, Sundays River Formation.

### *Locus typicus*

Borehole AL 1/69, cuttings sample at 1 240 feet.

### Description

Test compressed, elongate, with maximum width at the level of the final pair of chambers. Maximum depth of test, in initial portion, close to proloculus. In cross-section, adult portion of test elongate-ovate, with broad rounded margins and roughly parallel sides. Test periphery initially continuous, straight or weakly convex, later distinctly lobate in megalospheric tests; continuous and straight or slightly convex in microspheric tests. Chambers initially arranged in a polymorphinid manner, about four in number; later chambers biserially arranged, attaining up to four pairs. Chambers increase slowly and steadily in size as added, becoming about as wide as high in megalospheric tests and almost twice as wide as high in microspheric tests in the final part. Sutures initially flush, indistinct, becoming distinct and depressed, especially in megalospheric tests; declining at an angle of about forty-five degrees to the horizontal in the adult portion, straight to slightly curved. Aperture terminal, sited at the apical point of the last-formed chamber: radiate in form, composed of about 18 narrow slits that occasionally merge to form larger, more irregular openings. Apical point of test broad, rounded, unornamented. Surface of test smooth, unornamented.

### Remarks

Two major types of test can be recognized, which appear to be referable to the megalospheric (Fig. 65A–C) and microspheric (Fig. 65D–G) generations. *Pseudopolymorphina colchesterensis* lacks the peripheral keel and apical spine of both *P. martinezi* (Cañon & Ernst), described from the Esperanzian and Rinconian (?Oxfordian to Hauterivian) of the Magallanes Basin of southernmost Chile (see Cañon & Ernst 1974: 75, pl. 2 (fig. 8a–b); Malumíán & Masiuk 1975: 594, pl. 1 (fig. 2a–c), pl. 2 (fig. 1)), and of the informal species *P. 'carinata'*, present in the Early Barremian of South Africa (see 'Introduction' on DSDP site 249, p. 24).

*Pseudopolymorphina roanokensis*, described by Tappan (1940) from the mid-Cenomanian Grayson Formation of Texas, tends to become uniserial in the final part of the test, a feature not seen in the Sundays River species. The test outline of *Pseudopolymorphina* sp. from the Valanginian–Hauterivian Pampa Rincón Formation (Malumíán & Masiuk 1975, pl. 2 (fig. 2)) of Argentina is different from that of *P. colchesterensis*.

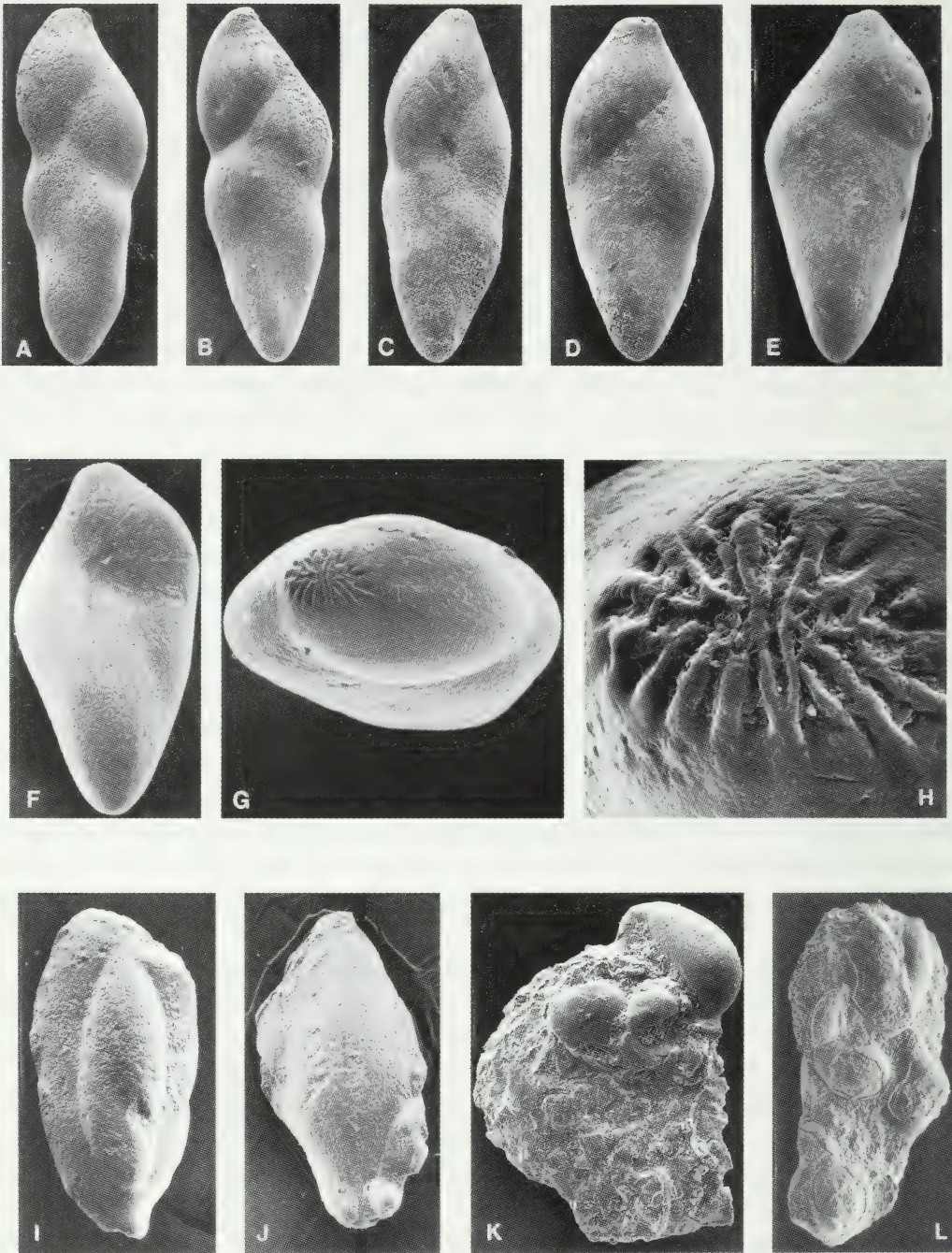


Figure 65.



Although not reported by McLachlan *et al.* (1976b), *P. colchesterensis* occurs in Pletmos Basin borehole PB-A1, and aids in correlating the Hauterivian sequences of the Pletmos and Algoa basins. It ranges there through the Late Hauterivian Biozone IV, and possibly into the top of Biozone V.

#### *Stratigraphic range in the Sundays River Formation*

Apparently confined to the Late Hauterivian Biozone IV, where it often occurs in considerable numbers. Typical of inner- to outer-shelf conditions, and seems to be able to tolerate some reduction in salinity, as it occurs in the top of the NA 3/70 section.

Genus *Pyrulina* d'Orbigny, 1839

*Pyrulina cylindroides* (Roemer, 1838)

Figs 66C–D

*Polymorphina cylindroides* Roemer, 1838: 385, pl. 3 (fig. 26).

*Pyrulina cylindroides* (Roemer). Tappan, 1940: 114, pl. 18 (fig. 1a–c). Dailey, 1973: 71, pl. 10 (fig. 11). McLachlan *et al.*, 1976a: 333, fig. 17 (no. 4).

#### *Remarks*

Rare specimens occur in the Sundays River Formation that are strongly fusiform, with the two last-formed chambers generally occupying most of the test. They are more elongate and narrower than the examples illustrated by Tappan (1940) and are closer to the test figured by Dailey (1973). It is difficult to determine how genetically close these Early Cretaceous individuals are to the original form described by Roemer (1838), which was from the Cainozoic of northern Germany. The degree of chamber overlap in authors' illustrations often differs greatly from that of the type illustration. For these reasons, no worldwide distribution of this species in the Early Cretaceous is given here, since it is clear the 'species' warrants a detailed investigation.

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Fig. 65 (see facing page). A–H. *Pseudopolymorphina colchesterensis* sp. nov. A. Paratype, SAM-PQ-MF1550, side view, Colchester Cliff outcrop sample 12001 (IV), F706. × 44. B. Paratype, SAM-PQ-MF1551, side view, Colchester Cliff outcrop sample 12001, (IV), F709. × 51. C. Paratype, SAM-PQ-MF1552, side view, Colchester Cliff outcrop sample 12001 (IV), F708. × 55. D. Paratype, SAM-PQ-MF1553, side view, Colchester Cliff outcrop sample 12001 (IV), F705. × 54. E. Holotype, SAM-PQ-MF1554, side view, AL 1/69, 1 240 feet (IV), F350. × 57. F. Paratype, SAM-PQ-MF1555, side view, AL 1/69, 1 210 feet (IV), F343. × 73. G. Paratype, SAM-PQ-MF1556, apertural view, AL 1/69, 1 210 feet (IV), F344. × 127. H. SAM-PQ-MF1556, close-up of aperture of G, F345. × 521. I–J. *Webbinella subhemisphaerica* Franke. I. SAM-PQ-MF1559, free test, AL 1/69, 520 feet (I), F193. × 45. J. SAM-PQ-MF1560, free test, AL 1/69, 460 feet (I), F108. × 64. K–L. *Bullopore laevis* (Sollas). K. SAM-PQ-MF1561, attached to *Ammobaculites subaequalis* fragment, shallow borehole SB-32, core 2, 2 feet below ?top (IV), F698. × 67. L. SAM-PQ-MF1562, attached to *Ammobaculites subaequalis*, AL 1/69, 1 540 feet (VI), F404. × 31.



*Stratigraphic range in the Sundays River Formation*

Apparently confined to the early Late Hauterivian (Biozones VII and VI).

Subfamily Webbinellinae Rhumbler, 1904

Genus *Webbinella* Rhumbler, 1904

*Webbinella subhemisphaerica* Franke, 1936

Fig. 65I–J

*Webbinella subhemisphaerica* Franke, 1936: 11, pl. 1 (fig. 4). McLachlan *et al.*, 1976a: 333, fig. 17 (no. 5); 1976b: 359, fig. 13 (no. 10). Kielbowicz *et al.*, 1983: 333, pl. 5 (fig. 3).

*Remarks*

Similarities to and differences from other closely related genera are given in the emended description of *Webbinella* by Loeblich & Tappan (1957: 226). In the South African tests of *W. subhemisphaerica*, variation exists in the size relationship between the polymorphinid portion of the test and the final flanged chamber. The final chamber is often severely damaged. All South African tests recognized so far, including those of McLachlan *et al.* (1976a), with the single exception of that illustrated by McLachlan *et al.* (1976b, fig. 13 (no. 10)), are found separated from the surface to which they were attached in life. The single exception, from borehole PB–A1, is attached to a shard of oyster shell.

Haynes (1981: 181, 198) considered the genera *Webbinella*, *Bullopore* and *Ramulina* to be ‘form genera’, reflecting possible growth stages in much the same way as fistulose growth chambers occur in some adult polymorphinids. Haynes regarded *Webbinella* as an attachment form produced by different polymorphinids. However, little difference can be seen in the initial chamber arrangement of South African examples, most of which would probably be assigned to *Eoguttulina* species if the final flanged chamber was absent. The three genera are here regarded as formal taxonomic units, bearing in mind that other ‘form genera’ have had a long and respectable taxonomic history (*Orbulina*, *Tretomphalus*).

*Occurrence*

Described from the Lias of northern Germany (Franke 1936). Southern Hemisphere records include: Valanginian Springhill Formation of southern Patagonia, Argentina (Kielbowicz *et al.* 1983); Late Valanginian (Biozones B and A) of Pletmos Basin borehole PB–A1 (McLachlan *et al.* 1976b) and Late Valanginian (Biozone B) of the Mngazana Basin, Transkei (McLachlan *et al.* 1976a), as well as the Portlandian Colchester Member of the Uitenhage Trough (McMillan 1980). In the southern offshore basins, *W. subhemisphaerica* ranges from Portlandian to Hauterivian, but it is always rare and is of no clear biostratigraphical value through the period.

*Stratigraphic range in the Sundays River Formation*

Occasional specimens occur from the Late Valanginian Biozone Bb to the Late Hauterivian Biozone I. It may prove to be associated with shell accumulations of the middle and outer shelf: it is usually absent closer to shore.

Genus *Bullopore* Quenstedt, 1856

*Bullopore laevis* (Sollas, 1877)

Figs 65K–L, 66A–B

*Webbina laevis* Sollas, 1877: 103, pl. 6 (fig. 1–3).

*Vitriwebbina laevis* (Sollas). Chapman, 1896b: 585, pl. 12 (fig. 12).

*Bullopore laevis* (Sollas). Tappan, 1940: 115, pl. 18 (fig. 6).

### Remarks

Much confusion has existed over *Bullopore laevis* in the past, as authors subsequent to Sollas (1877) have included several different attached forms under this name. Adams (1962: 153–155) gave detailed comments on the genus *Bullopore*, regarded by him as possessing a ?radial hyaline test wall, which is 'adherent, consisting of a linear or curvilinear series of chambers that are variable in shape but commonly subglobular or pyriform. Proloculus separate from, or partially embraced by, the second chamber. There is no initial coil. Wall calcareous, vitreous in appearance when well preserved, probably perforate; in thin section showing its radiate fibrous structure'. It is evident that polymorphinid forms with a final spreading chamber (vide *Bullopore* cf. *laevis* of Bartenstein & Brand 1951, pl. 11 (figs 303a–b and 304a–b)) should be transferred to *Webbinella*.

The morphology of the chambers of Sundays River Formation tests compare well with the illustrated specimens of Sollas (1877). Chambers vary from circular to pyriform to elongate-ovate in outline. In all cases the stoloniferous necks are either short, or not visible if the chambers are closely appressed. Most *B. laevis* in the Sundays River Formation are found clinging to tests of *Ammobaculites*, especially *A. subaequalis* Mjatluk, comparatively few are adhering to shell fragments, and none embrace individual quartz grains.

### Occurrence

*Bullopore laevis* was described from the Cambridge Greensand (Cenomanian) of England (Sollas 1877). Other records include: Gault Clay (Albian) of Folkestone, England (Chapman 1896b); Aptian (Damotte & Magniez-Jannin 1973) and Albian (Magniez-Jannin 1975) of the Aube region, France; Hauterivian (Ten Dam 1948) and Albian (Ten Dam 1950) of the Netherlands; middle and late Valanginian of north-western Germany (Bartenstein & Brand 1951); middle Cenomanian Grayson Formation (Tappan 1940) and Late Albian Duck Creek Formation (Tappan 1943, *pars*) of Texas and Oklahoma, U.S.A.; and Portlandian Colchester Member of the Uitenhage Trough, Algoa Basin (McMillan 1980).

### Stratigraphic range in the Sundays River Formation

Present in small numbers in the Late Valanginian (Biozones Bb and Ba); more common, especially in sandstone intervals where *A. subaequalis* predominates, in the Early and Late Hauterivian (Biozones VIII to II). Ranges from marginal-marine to outermost-shelf environments, but is more common on the deeper parts of the shelf.



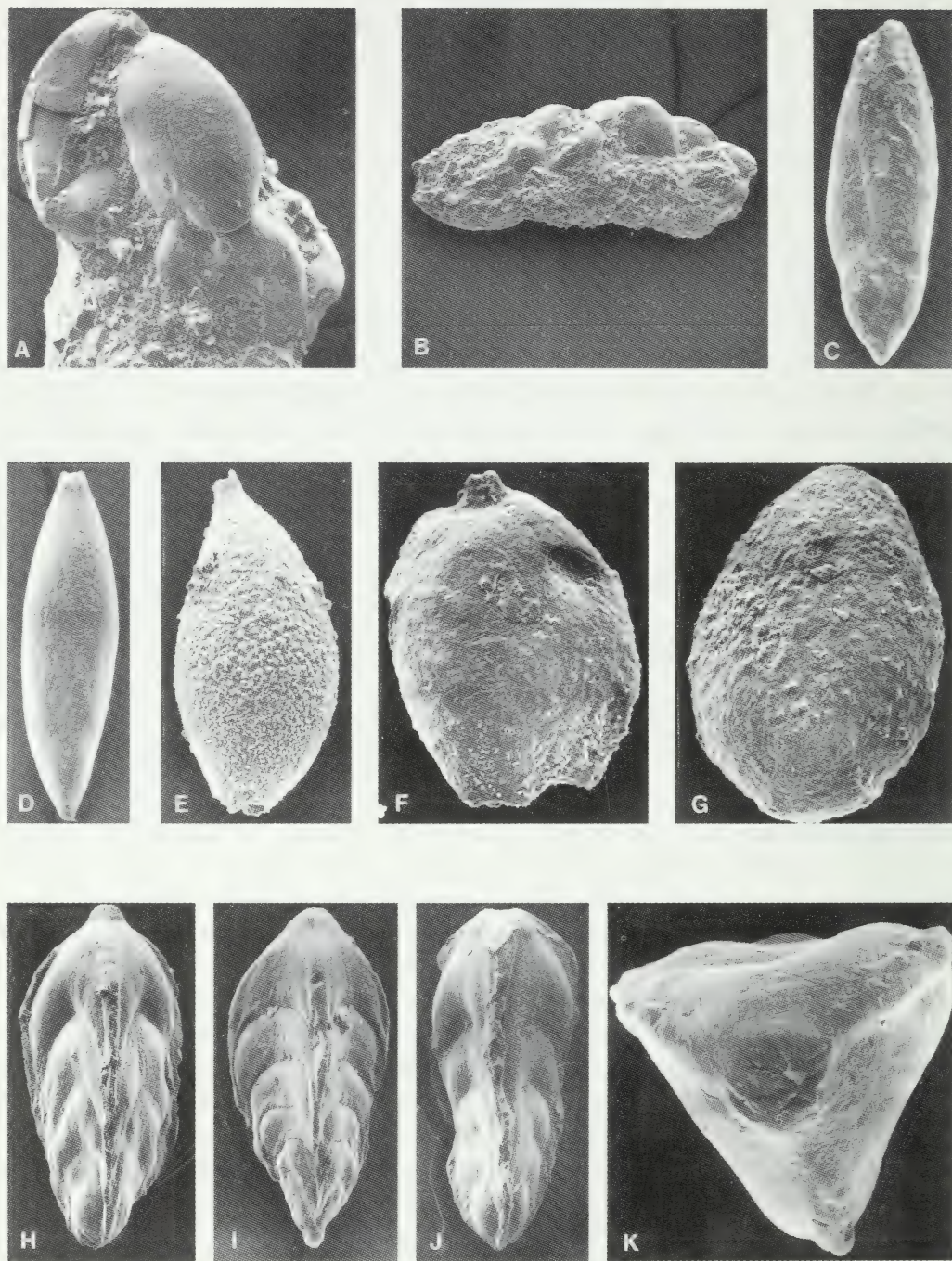


Figure 66.



Subfamily Ramulininae Brady, 1884

Genus *Ramulina* T. R. Jones, 1875

*Ramulina fusiformis* Khan, 1950

Fig. 66E

*Ramulina fusiformis* Khan, 1950: 272, pl. 2 (figs 1–2). Seibold & Seibold, 1960: 371, text-fig. 7h.

Magniez-Jannin, 1975: 230, pl. 15 (fig. 21), text-fig. 122.

*Ramulina tappanae* Bartenstein & Brand, 1951: 322, pl. 11 (figs 305–307).

### Remarks

A few specimens referable to *Ramulina fusiformis* occur in the Zoetogeneugd Cliff outcrop samples. The finely acicular ornament of these tests is variably affected by secondary calcite crystallization in all studied tests. All examples are composed of one chamber with long, rather tubular stoloniferous necks. Magniez-Jannin (1975) has illustrated the variations evident in chamber outline and neck morphology in her Albian material. This species differs from *R. aculeata* (d'Orbigny) (see Loeblich & Tappan 1964: C537, fig. 420 (no. 8)) in its finer, denser hispid ornament and much narrower stoloniferous necks.

### Occurrence

First described from the Gault Clay (Albian) of England (Khan 1950). Other records include: Late Berriasian to latest Hauterivian of the Speeton Clay, north-east England (Fletcher 1973); Albian of the Aube district, France (Magniez-Jannin 1975); middle Cenomanian Grayson Formation of Texas (Tappan 1940, as *Ramulina* sp.); Valanginian of north-west Germany (Bartenstein & Brand 1951, as *R. tappanae*); Oxfordian of southern Germany (Seibold & Seibold 1960); and Portlandian Colchester Member of the Uitenhage Trough, Algoa Basin (McMillan 1980).

### Stratigraphic range in the Sundays River Formation

Occurs in small numbers in the basal Biozone Bb, Late Valanginian. Apparently restricted to innermost-shelf environments.

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Fig. 66 (see facing page). A–B. *Bullopore laevis* (Sollas). A. SAM–PQ–MF1563, attached to *Ammobaculites subaequalis*, AL 1/69, 1 270 feet (IV), F365.  $\times 50$ . B. SAM–PQ–MF1564, attached to *Ammobaculites subaequalis*, shallow borehole SB–32, core 2, 2 feet below ?top (IV), F697.  $\times 26$ . C–D. *Pyrulina cylindroides* (Roemer). C. SAM–PQ–MF1557, side view, AL 1/69, 1 540 feet (VI), F407.  $\times 99$ . D. SAM–PQ–MF1558, side view, AL 1/69, 1 780 feet (VII), F449.  $\times 143$ . E. *Ramulina fusiformis* Khan, SAM–PQ–MF1565, side view, Zoetogeneugd Cliff outcrop sample 11450 (Bb), F240.  $\times 96$ . F–G. *Ramulina* spp. F. SAM–PQ–MF1566, side view, MV 1/79, 150 m (X), F588.  $\times 126$ . G. SAM–PQ–MF1567, side view, MV 1/79, 150 m, (X), F589.  $\times 127$ . H–K. *Tristix acutangula* (Reuss). H. SAM–PQ–MF1568, side view, AL 1/69, 640 feet (II), F189.  $\times 67$ . I. SAM–PQ–MF1569, side view, AL 1/69, 1 090 feet (III), F331.  $\times 129$ . J. SAM–PQ–MF1570, side view, AL 1/69, 790 feet (III), F225.  $\times 76$ . K. SAM–PQ–MF1571, apertural view, AL 1/69, 1 090 feet (III), F330.  $\times 249$ .

*Ramulina* spp.

Figs 66F–G

*Remarks*

A number of crushed, damaged specimens probably of separated *Ramulina* chambers. The two specimens illustrated, from Biozone X (earliest Early Hauterivian) appear to be either smooth-walled or slightly rugose. These may be identical to the *R. aculeata* (d'Orbigny) Wright of Kielbowicz *et al.* (1983, pl. 4 (fig. 11)) from the Valanginian Springhill Formation of southern Patagonia.

Family **Glandulinidae** Reuss, 1860

Subfamily Glandulininae Reuss, 1860

Genus *Tristix* Macfadyen, 1941*Tristix acutangula* (Reuss, 1863)

Figs 66H–K, 67A

*Rhabdogonium acutangulum* Reuss, 1863: 55, pl. 4 (fig. 14a–b).*Tristix acutangula* (Reuss). Damotte & Magniez-Jannin, 1973: 37, pl. 4 (figs 14–15). Magniez-Jannin, 1975: 222, pl. 12 (figs 2–6). Bartenstein & Kovatcheva, 1982: 646, pl. 3 (figs 29–30).*Tristix acutangulus* (Reuss). Beer, 1970: 16, pl. 3 (fig. 6a–b). McLachlan *et al.*, 1976a: 334, fig. 17 (no. 6); 1976b: 359, fig. 13 (no. 11). Musacchio, 1979: 258, pl. 4 (fig. 21). Kielbowicz *et al.*, 1983: 333, pl. 5 (figs 4–5).*Tristix* sp. Malumián & Masiuk, 1975: 593, pl. 2 (fig. 16).*Remarks*

Widely recorded, especially in the boreal and austral Early Cretaceous. The specimen figured by Reuss (1863) and many of those illustrated by later authors (e.g. Damotte & Magniez-Jannin 1973; Magniez-Jannin 1975) contain up to 11 chambers, but the maximum number in South African tests is about eight, with five or six being usual. Individuals with fewer chambers also seem to be the norm in Argentina (Malumián & Masiuk 1975; Musacchio 1979; Kielbowicz *et al.* 1983). There are differences too in the intensity and form of the peripheral margins amongst authors' illustrated tests, which vary from sub-angular and entirely lacking any peripheral ornamentation, to angular with a thickened and raised margin, to fully carinate.

In South Africa, *Tristix acutangula* is the longest ranging and commonest species of the genus, and is the only one to be found in strata later than the Hauterivian. Its full range is Early Portlandian to Middle Cenomanian, although it is usually absent in the poorly oxygenated environments of the Barremian to Early Aptian sequence. No South African specimens of the quadrate variety have been found at any level in the Late Jurassic or Early Cretaceous.

*Occurrence*

This species was described by Reuss (1863) from the middle and upper Hils Clays

(Barremian–Aptian) of northern Germany. Most records are from the Early Cretaceous: Aptian (Damotte & Magniez-Jannin 1973) and Albian (Magniez-Jannin 1975) of France; Berriasian to Early Barremian of the Speeton Clay sequence, north-east England (Fletcher 1973); Late Barremian to Early Albian of north-west Germany and Late Barremian to Late Aptian of Bulgaria (Bartenstein & Kovatcheva 1982); Late Hauterivian of Neuquén (Musacchio 1979), Valanginian–Hauterivian Pampa Rincón Formation, Tierra del Fuego (Malumián & Masiuk 1975), and the Valanginian Springhill Formation, southern Patagonia (Kielbowicz *et al.* 1983), all of Argentina. In South Africa the species occurs in the Late Valanginian (Biozone B) of Mngazana Basin, Transkei (McLachlan *et al.* 1976a), the earliest Late Valanginian (Biozone D) Brenton Formation of the southern Cape coast (McLachlan *et al.* 1976b) and in the Portlandian Colchester Member of the Uitenhage Trough, Algoa Basin (McMillan 1980).

#### *Stratigraphic range in the Sundays River Formation*

Present in small numbers throughout the sequence, from Biozone Bb to Biozone I, but occurs most frequently in the Late Hauterivian (Biozones VII to I). Although the species tolerates shallow marine, oxygenated conditions, as at Brenton and in the Colchester Member, it appears to have avoided reduced salinity and poorly oxygenated conditions. Its full environmental range seems to be innermost to outer shelf.

#### *Tristix excavata* (Reuss, 1863)

Figs 67B–E

*Rhabdogonium excavatum* Reuss, 1863: 91, pl. 12 (fig. 8a–c). Chapman, 1894a: 160, pl. 4 (fig. 9a–b). Noth, 1951: 81, pl. 2 (fig. 41a–b).

*Tristix excavata* (Reuss). Neagu, 1965: 24, pl. 5 (figs 14–15). Dailey, 1973: 66, pl. 9 (fig. 11). Magniez-Jannin, 1975: 224, pl. 12 (figs 7–11). Bertels, 1990: 279, pl. 7 (fig. 14).

#### *Remarks*

Four Sundays River Formation tests only are referable here. Two are weakly carinate along the margins (Fig. 67B–C); this feature is not evident in Reuss's original illustrations, but can be seen to a slight degree in some of the Late Albian individuals figured by Magniez-Jannin (1975). However, the South African tests display a stronger, more continuous carina than that seen in the French Albian examples, and perhaps are closest to that illustrated by Bertels (1990). The remaining two Sundays River tests exhibit broadly rounded, non-carinate margins.

Of more critical importance is the nature of the aperture and the presence or absence of an entosolenian tube in the chamber cavity. Loeblich & Tappan (1988) reinstated the genus *Tricarinella* Ten Dam & Schijfsma on the basis of the description and illustrations of Van Voorthuysen (1947), and emphasized these features in the distinction of *Tricarinella* from *Tristix*. Thus *Tricarinella* possesses an entosolenian tube and *Tristix* does not; *Tricarinella* has a triradiate aperture whereas that of *Tristix* is multiradiate; and tests of *Tricarinella* are deeply excavated whereas those of *Tristix* are more nearly



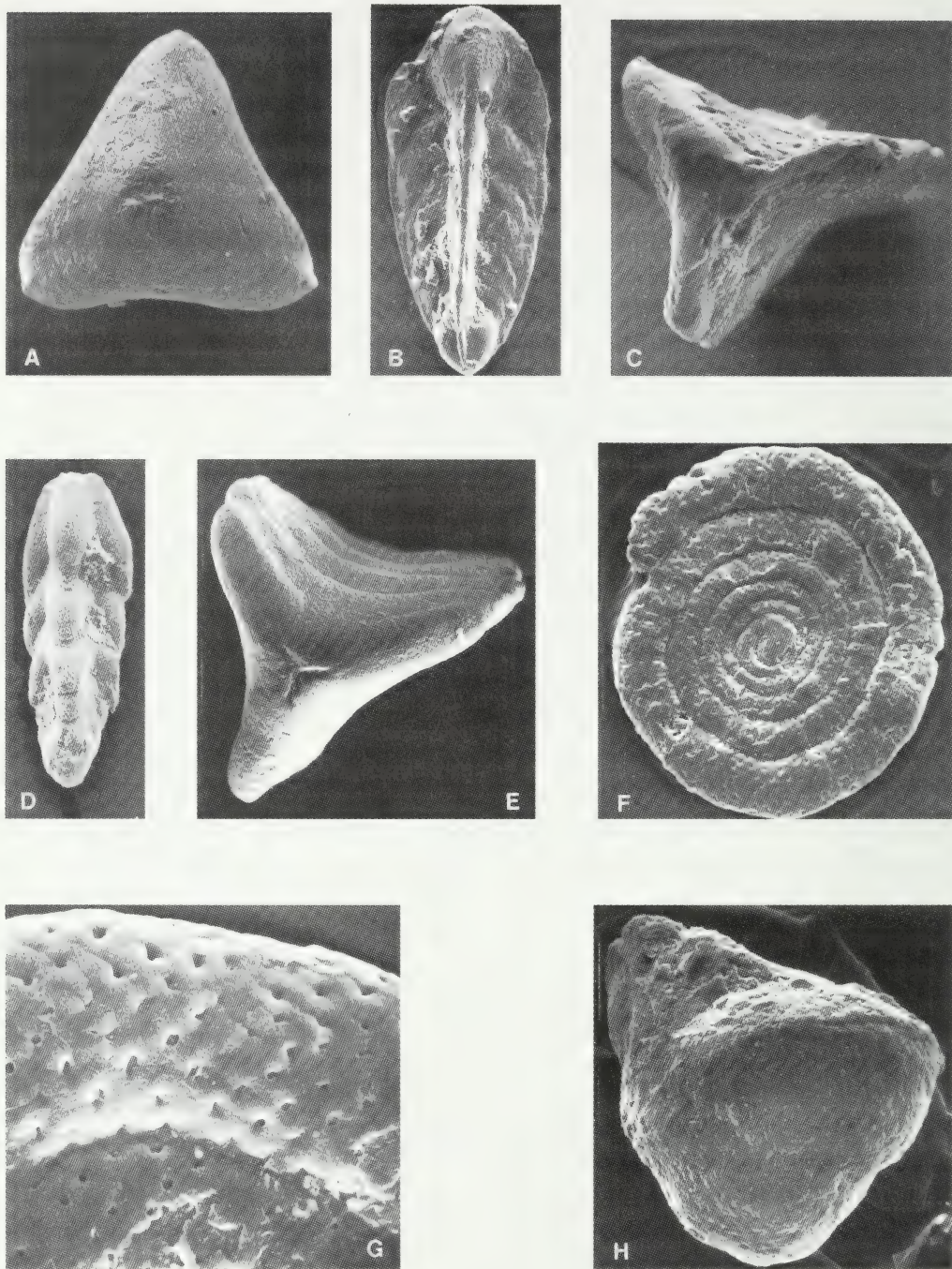


Figure 67.

flat-sided. However, examination of the Sundays River material reveals the presence of deeply excavated tests with both simple circular and triradiate apertures (Fig. 67C, E). None of these tests is as deeply excavated or as lobate as that illustrated by Van Voorthuysen (1947). Multiradiate or simple circular openings are typical of many tests referred to this species (Bertels 1990, description; Magniez-Jannin 1975; Chapman 1894a; Neagu 1965; Noth 1951; and, seemingly, Reuss 1863). Some concern must exist that the specimens figured and described by Van Voorthuysen (1947) may be morphologically somewhat different from Reuss' type specimen, particularly with regard to the nature of the margins of the chamber lobations (more nearly rounded or more acute) and to the aperture form (triradiate or simple, circular). Recognition of the genus *Tricarinelina* (as amended by Loeblich & Tappan 1988) can only be warranted if the distinctive features of the genus (entosolenian tube, triradiate aperture) are identified in Reuss's holotype of *Rhabdogonium excavatum* or in a designated replacement test. No clear connection has been proven between presence of triradiate aperture, entosolenian tube and deeply excavated sides of the test. Until a more detailed study of the *Tristix* group has been undertaken, it seems premature to separate particular tests to *Tricarinelina* on the basis of the amended generic description given by Loeblich & Tappan (1988). The few specimens available from the Sundays River Formation preclude a detailed thin section analysis; in external view none permit examination of the test interior or identification of any entosolenian tube because of the opacity of the test.

### Occurrence

Described by Reuss (1863) from the Gault Clay (Albian) of Folkestone, England. Later records in Europe tend to be of the same age: Albian of Romania (Neagu 1965); Albian of France (Magniez-Jannin 1975); Albian of the Netherlands (Ten Dam 1950); Albian of Austria (Noth 1951); Albian of California (Dailey 1973), middle Cenomanian Grayson Formation (Tappan 1940), and late Albian Duck Creek Formation (Tappan 1943) of Texas and Oklahoma, U.S.A.; and the Hauterivian of southern Argentina (Bertels 1990).

### Stratigraphic range in the Sundays River Formation

Late Valanginian Biozone Bb and the Late Hauterivian Biozones VI to II only. Its environmental range seems to be similar to that of *Tristix acutangula* (Reuss).

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Fig. 67 (see facing page). A. *Tristix acutangula* (Reuss), SAM-PQ-MF1572, apertural view, AL 1/69, 1 600 feet (VI), F436.  $\times 63$ . B-E. *Tristix excavata* (Reuss). B. SAM-PQ-MF1573, side view, shallow borehole SB-15, core 4, 229 feet (II), F686.  $\times 103$ . C. SAM-PQ-MF1574, apertural view, AL 1/69, 1 570 feet (VI), F431.  $\times 78$ . D. SAM-PQ-MF1575, side view, Uitenhage to Graaff-Reinet Road outcrop, sample 11464 (Bb), F78.  $\times 111$ . E. SAM-PQ-MF1576, apertural view, AL 1/69, 610 feet (II), F180.  $\times 169$ . F-G. *Spirillina tenuissima* Gümbel. F. SAM-PQ-MF1577, side view, shallow borehole SB-15, core 3, 215 feet (II), F682.  $\times 245$ . G. SAM-PQ-MF1577, close-up of test perforations of F, F683.  $\times 909$ . H. *Conorboides* sp. A, SAM-PQ-MF1578, side view, MV 1/79, 360-370 m (Ba), F643.  $\times 294$ .



Family **Spirillinidae** Reuss, 1862  
Genus *Spirillina* Ehrenberg, 1843  
*Spirillina tenuissima* Gümbel, 1862  
Figs 67F–G

*Spirillina tenuissima* Gümbel, 1862: 214, pl. 13 (fig. 2). Seibold & Seibold, 1955: 125 (fig. 5n). Espitalié & Sigal, 1963: 65, pl. 30 (figs 19–20). Hanzlíková, 1965: 93, pl. 9 (figs 19, 23a–b). Winter, 1970: 42, pl. 4 (fig. 144a–b). McLachlan *et al.*, 1976a: 334, fig. 17 (no. 10). Barnard *et al.*, 1981, 428, pl. 4 (figs 4, 8). Gregory, 1989: 188, pl. 1 (fig. 23).

*Remarks*

A single specimen from the Late Hauterivian (Biozone II) is clearly referable to *Spirillina*. The genus, so well represented at Mngazana on the Transkei coast, is generally absent throughout the Kimmeridgian to Hauterivian of the nearshore Pletmos, Gamtoos and Algoa basins. Occasional examples occur in the more distal Late Valanginian of the Gamtoos Basin, and it appears that the genus is commonest on the continental slope during the latest Jurassic and earliest Cretaceous in South Africa. The Sundays River and Mngazana tests compare closely in terms of the number and size of the whorls, and the density of the test perforations.

*Occurrence*

Described by Gümbel (1862) from the Oxfordian of southern Germany. Most subsequent records are from the Jurassic of Europe; later Jurassic records including latest Oxfordian to Kimmeridgian Klentnice Beds, Czech Republic (Hanzlíková 1965); Kimmeridgian of south-eastern Germany (Winter 1970); Callovian–Oxfordian of England (Barnard *et al.* 1981); and Kimmeridgian of north-east Scotland (Gregory 1989). In Madagascar, Espitalié & Sigal (1963) reported it from the Kimmeridgian to Early Valanginian (Cenozones C and D); and McLachlan *et al.* (1976a) recognized it in the Late Valanginian (Biozone B) of the Mngazana Formation, Transkei, South Africa.

Family **Conorboididae** Thalmann, 1952  
Genus *Conorboides* Hofker, 1952  
*Conorboides* sp. A  
Figs 67H, 68A

*Remarks*

Occasional specimens of a high-spired, aragonitic-walled form, with just over two chambers per whorl in the adult part of the test, and a closed umbilicus. Sutures flush to weakly depressed, generally only faintly visible unless the test is moistened. The aperture is not well preserved in any of the tests studied, but would seem to be a low elongate slit extending from the umbilicus out towards the test periphery. The absence of a clear aperture, the high trochospiral coiling and the closed umbilicus suggest this species is better referred to *Conorboides* than to *Pseudolamarckina*, but more, well-preserved tests



are necessary before this identification can be confirmed.

*Conorboides* sp. A compares closely with an undescribed species mainly occurring in the latest Valanginian to Early Barremian off the south coast of South Africa, and the two may prove to be conspecific. *Conorboides* sp. A has not been found at time-equivalent horizons in the earlier Late Valanginian in the offshore Pletmos, Gamtoos or Algoa basins off South Africa.

### *Stratigraphic range in the Sundays River Formation*

Confined to Biozone Ba of the Late Valanginian, only on the middle and outer shelf.

Family **Epistominidae** Wedekind, 1937

Genus *Epistomina* Terquem, 1883

*Epistomina hechti* Bartenstein, Bettenstaedt & Bolli, 1957

Figs 68B–H

*Epistomina (Brotzenia) hechti* Bartenstein *et al.*, 1957: 46, pl. 7 (fig. 170a–c).

*Epistomina hechti* Bartenstein, Bettenstaedt & Bolli. Ohm, 1967: 138, pl. 18 (fig. 6a–b).

Bartenstein *et al.*, 1971: 149, text-fig. 3 (nos 61–65). Ascoli, 1976: 674, pl. 4 (fig. 1a–d). Butt, 1979: 259, pl. 2 (fig. 4,7).

*Epistomina* sp. McLachlan *et al.*, 1976b: 359, fig. 13 (nos 20–21, *non* nos 17–19).

see *Epistomina* cf. *ornata* (*non* Roemer): Musacchio, 1979: 258, pl. 5 (fig. 8).

see *Epistomina hechti* (*non* Bartenstein, Bettenstaedt & Bolli): Hart *et al.*, 1981: 188, pl. 7.8 (fig. 5–7).

### *Remarks*

Variably preserved, ornamented *Epistomina* tests occur at two horizons in the upper Sundays River Formation, and are used to mark the tops of Biozones V and II. The lower part of the later of these also occurs near the top of the Pletmos Basin borehole PB–A1 (McLachlan *et al.* 1976b). These tests possess a distinctive sutural ribbing pattern that extends also around the old, secondarily infilled sub-peripheral apertures and is at its most complex over the umbilical area of the ventral side. Sutural ribs on the ventral side are very weakly curved and tend to thin significantly from the umbilicus towards the test periphery. The dorsal intercameral sutural ribs curve gently and obliquely to the test margin. The Biozone V and Biozone II tests are similarly ornamented, but can be easily distinguished by their different states of preservation.

The original description and illustrations of *Epistomina hechti* by Bartenstein *et al.* (1957) give few details of the rib patterning. The South African examples possess similar oblique dorsal sutures to those of Bartenstein *et al.* (1957), but their ventral sutures are not so curved. Comparison with the Canadian tests figured by Ascoli (1976) shows a close similarity, although the detail of the ribbing pattern over the ventral umbilicus shows differences.

The shells identified as *Epistomina* sp. by McLachlan *et al.* (1976b) that derive from the Late Valanginian are referable to another species, *E. australis* Masiuk & Viña (see below). The sutural ribs of *E. hechti* are more delicate, less limbate and more sharply

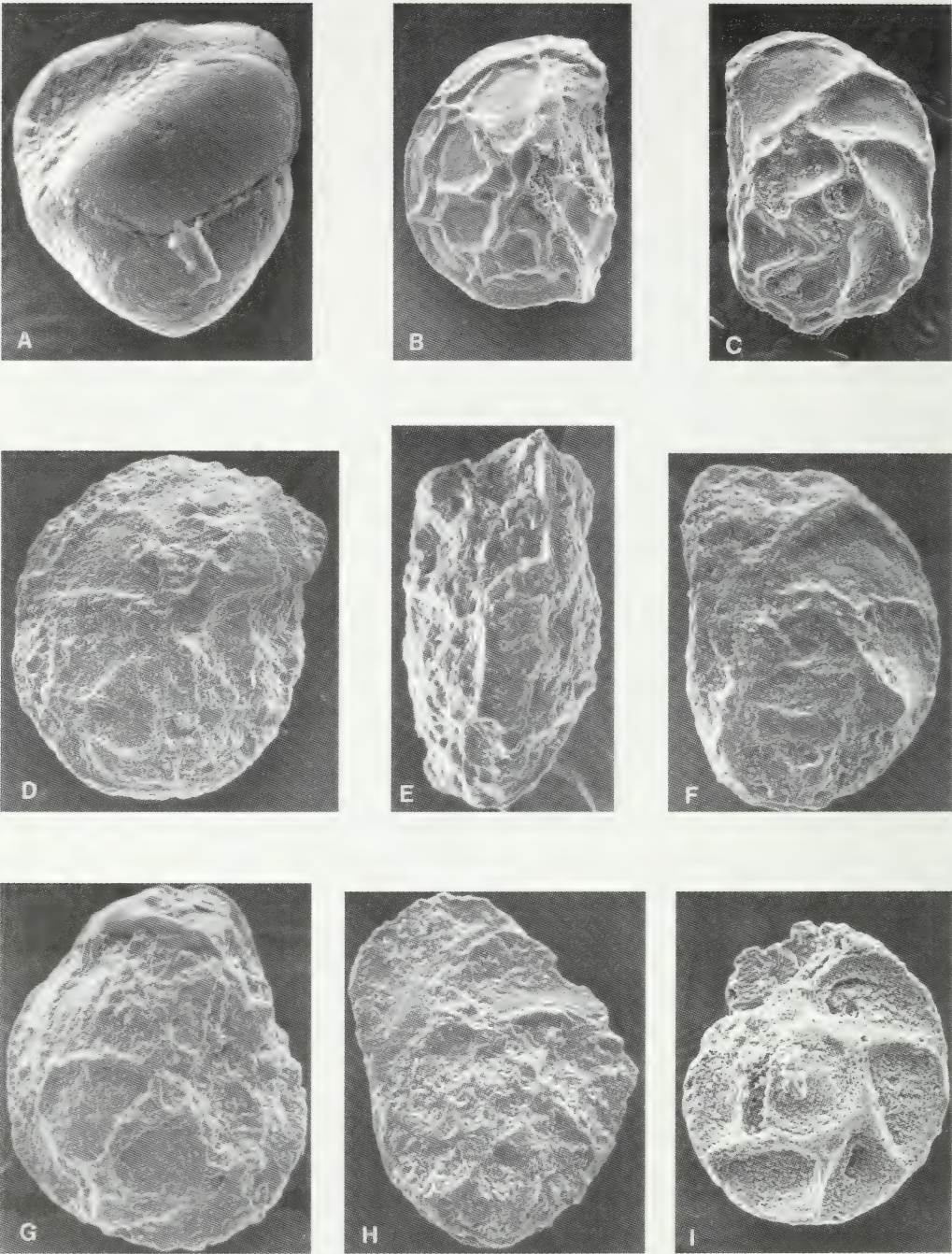


Figure 68.



defined, and the tests more strongly biconvex than seen in *E. australis*. A similarly ornamented *Epistomina* has been reported by McMillan (1990a), as *Epistomina* cf. *hechti*, from probable Late Barremian black silty claystones in Core 2 of borehole Kudu 9A–2, southernmost offshore Namibia. It has proved very difficult to confirm if the Algoa Basin and Kudu forms are the same, since the ornamentation of the latter is very poorly preserved in all specimens due to their subsequent deep burial (over 4 000 m). Ornamented *Epistomina* of this type, however, are absent in the Barremian to Early Aptian (6At1 to 13At1) of the Bredasdorp, Pletmos and Zululand basins.

### Occurrence

Originally from the early and middle Barremian of north-west Germany, as *Epistomina* D7 (Hecht 1938) and described from the middle Barremian of Trinidad (Bartenstein *et al.* 1957). Other records include: Barremian of Atlantic offshore Canada (Ascoli 1976); latest Early to earliest Late Barremian of north-west Germany and Late Barremian of Bulgaria (Bartenstein *et al.* 1971); Late Hauterivian and Early Barremian of DSDP site 397 off Cape Bojador, north-west Africa (Butt 1979); middle Barremian of the Speeton Clay, north-east England (Fletcher 1973); probably the Early and Late Hauterivian of Neuquén, Argentina (Musacchio 1979); and Late Hauterivian (Biozone V to Biozone II) of PB–A1 borehole, Pletmos Basin, South Africa (McLachlan *et al.* 1976b).

### Stratigraphic range in the Sundays River Formation

Restricted to Biozones VII to top V, and Biozone II, all Late Hauterivian. Confined to middle- and outer-shelf localities.

### *Epistomina australis* Masiuk & Viña, 1986

Figs 68I, 69A

*Epistomina* sp. McLachlan *et al.*, 1976b: 359, fig. 13 (nos 17–19, *non* nos 20–21).

*Epistomina caracolla caracolla* (*non* Roemer): Stapleton & Beer 1977: 2, pl. 3 (figs 13a–b).

*Epistomina australis* Masiuk & Viña, 1986a: 17, pl. 1 (figs 10–14).

### Remarks

Numerous, although usually poorly preserved, ornamented *Epistomina* specimens

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Fig. 68 (*see facing page*). A. *Conorboides* sp. A. SAM–PQ–MF1579, side view, MV 1/79, 350–360 m. (Ba), F658. × 271. B–H. *Epistomina hechti* Bartenstein, Bettenstaedt & Bolli. B. SAM PQ MF1580, ventral view, AL 1/69, 550 feet (II), F165. × 102. C. SAM–PQ–MF1581, dorsal view, AL 1/69, 550 feet (II), F164. × 99. D. SAM–PQ–MF1582, ventral view, AL 1/69, 1 510 feet (V), F397. × 113. E. SAM–PQ–MF1583, side view, AL 1/69, 1 510 feet (V), F399. × 188. F. SAM–PQ–MF1584, dorsal view, AL 1/69, 1 510 feet (V), F398. × 176. G. SAM–PQ–MF1585, ventral view, AL 1/69, 2 110 feet (VIII), F492. × 126. H. SAM–PQ–MF1586, dorsal view, AL 1/69, 1 930 feet (VII), F468. × 135. I. *Epistomina australis* Masiuk & Viña, SAM–PQ–MF1587, dorsal view, Zoetgeneugd Cliff outcrop sample 11450 (Bb), F243. × 148.



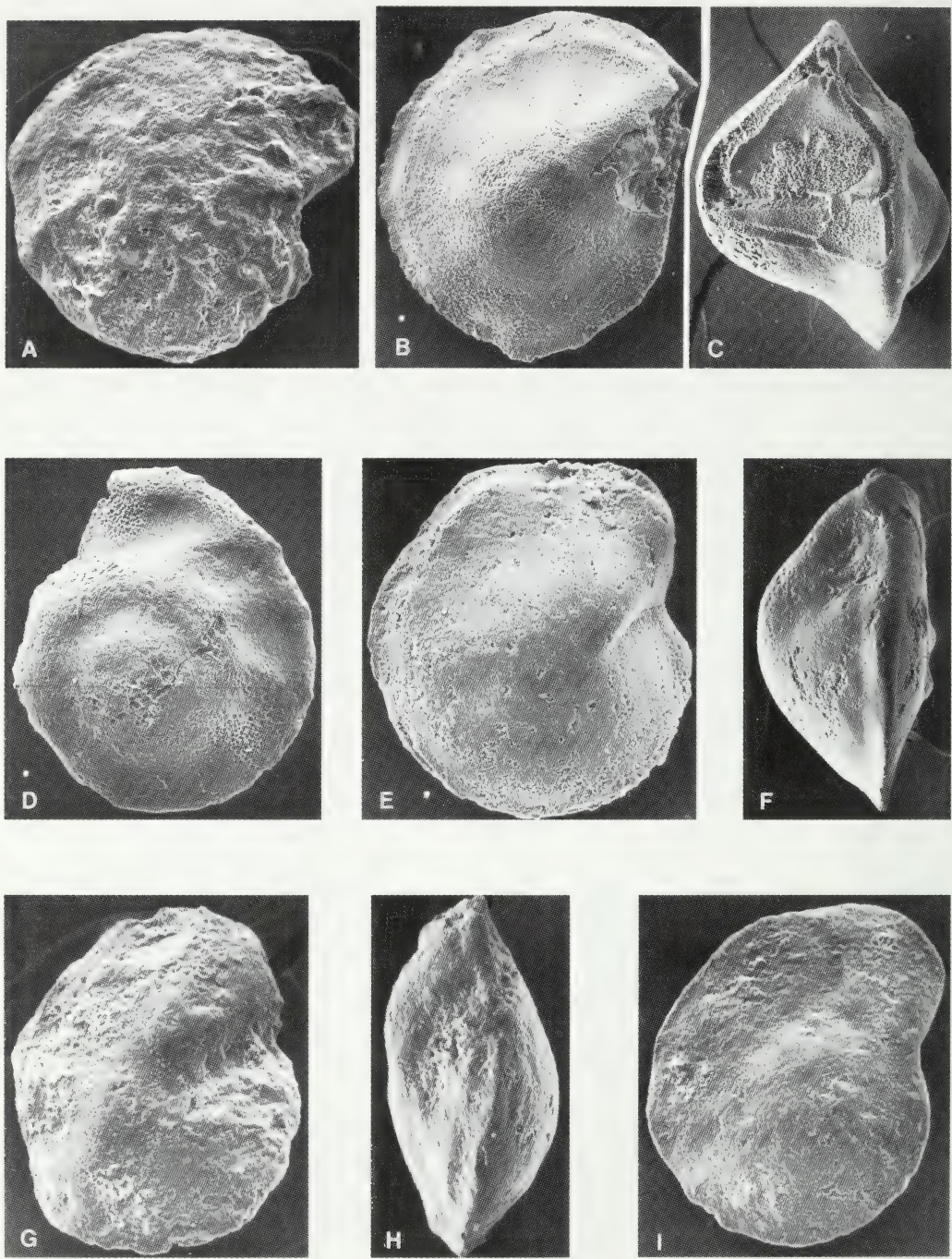


Figure 69.

occur in the Late Valanginian that appear best referred to *E. australis* Masiuk & Viña. However, it is not clear whether all Masiuk & Viña's specimens are referable to *E. australis* or *E. hechti* Bartenstein, Bettenstaedt & Bolli, as here understood, since test preservation is very variable. Tests closest to *E. australis* are confined to the Late Valanginian in the Sundays River Formation sequence.

Sutures are ornamented by low, limbate ribs on both sides of the test. There is an area of fine reticulations over the ventral umbilicus in well-preserved tests. The dorsal sutures are straight or weakly curved, oblique; and the ventral sutures radiate, straight or weakly curved. The sutural ribs tend to be broader and more substantial than those of *E. hechti*, and the tests are more plano-convex, with a nearly flat dorsal side in many cases. The generally poor preservation has prevented a detailed analysis of this species. It is almost always found in association with abundant *E. caracolla* (Roemer) s.l., in the strata affected by the lowered-oxygen conditions of Biozone Bb and Ba.

### Occurrence

*Epistomina australis* was described from the Upper Agrio Formation (Late Hauterivian) of Neuquén, southern Argentina. It also ranges from Biozone C to early Biozone A in the Late Valanginian of Pletmos Basin borehole PB-A1 and is present in the Brenton Formation (Biozone D) (McLachlan *et al.* 1976b) in South Africa.

### Stratigraphic range in the Sundays River Formation

Confined to Biozone C to top Ba (Late Valanginian). Ranges from well-oxygenated innermost shelf to poorly oxygenated middle- and outer-shelf environments.

### *Epistomina caracolla* (Roemer, 1841) s.l.

Figs 69E–I, 70A–I, 72A–E

see *Gyroidina caracolla* Roemer, 1841: 97, pl. 15 (fig. 22).

see *Epistomina caracolla caracolla* (non Roemer): Beer, 1970: 18, pl. 3 (fig. 9a–c).

*Epistomina* ex gr. *caracolla* (Roemer). Rigassi, 1970: pl. 83 (pars).

see *Epistomina caracolla* (Roemer). Ascoli, 1976: 684, pl. 3 (fig. 10a–c), pl. 14 (fig. b). Butt, 1979: 259, pl. 2 (figs 2–3, 5). Lott *et al.*, 1986: 44 (fig. 4G–H).

see *Epistomina* (*Hoeglundina*) *caracolla* (Roemer). Espitalié & Sigal, 1963: 68, pl. 32 (fig. 6a–c).

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Fig. 69 (see facing page). A. *Epistomina australis* Masiuk & Viña, SAM-PQ-MF1588, ventral view, MV 1/79, 360–370 m (Ba), F645. × 87. B–D. *Epistomina caracolla* (Roemer) s.s. B. SAM-PQ-MF1589, ventral view, Late Hauterivian (C5/C4), Speeton Clay, Filey, Yorkshire coast, England, F98. × 72. C. SAM-PQ-MF1590, side view, Late Hauterivian (C5/C4), Speeton Clay, Filey, Yorkshire coast, England, F100. × 66. D. SAM-PQ-MF1591, dorsal view, Late Hauterivian (C5/C4), Speeton Clay, Filey, Yorkshire coast, England, F99. × 78. E–I. *Epistomina caracolla* (Roemer) s.l. E. SAM-PQ-MF1592, ventral view, AL 1/69, 460 feet (I), F109. × 117. F. SAM-PQ-MF1593, side view, AL 1/69, 760 feet (II), F218. × 84. G. SAM-PQ-MF1594, ventral view, AL 1/69, 1 240 feet (IV), F357. × 129. H. SAM-PQ-MF1595, side view, AL 1/69, 1 240 feet (IV), F355. × 141. I. SAM-PQ-MF1596, dorsal view, AL 1/69, 1 240 feet (IV), F354. × 132.



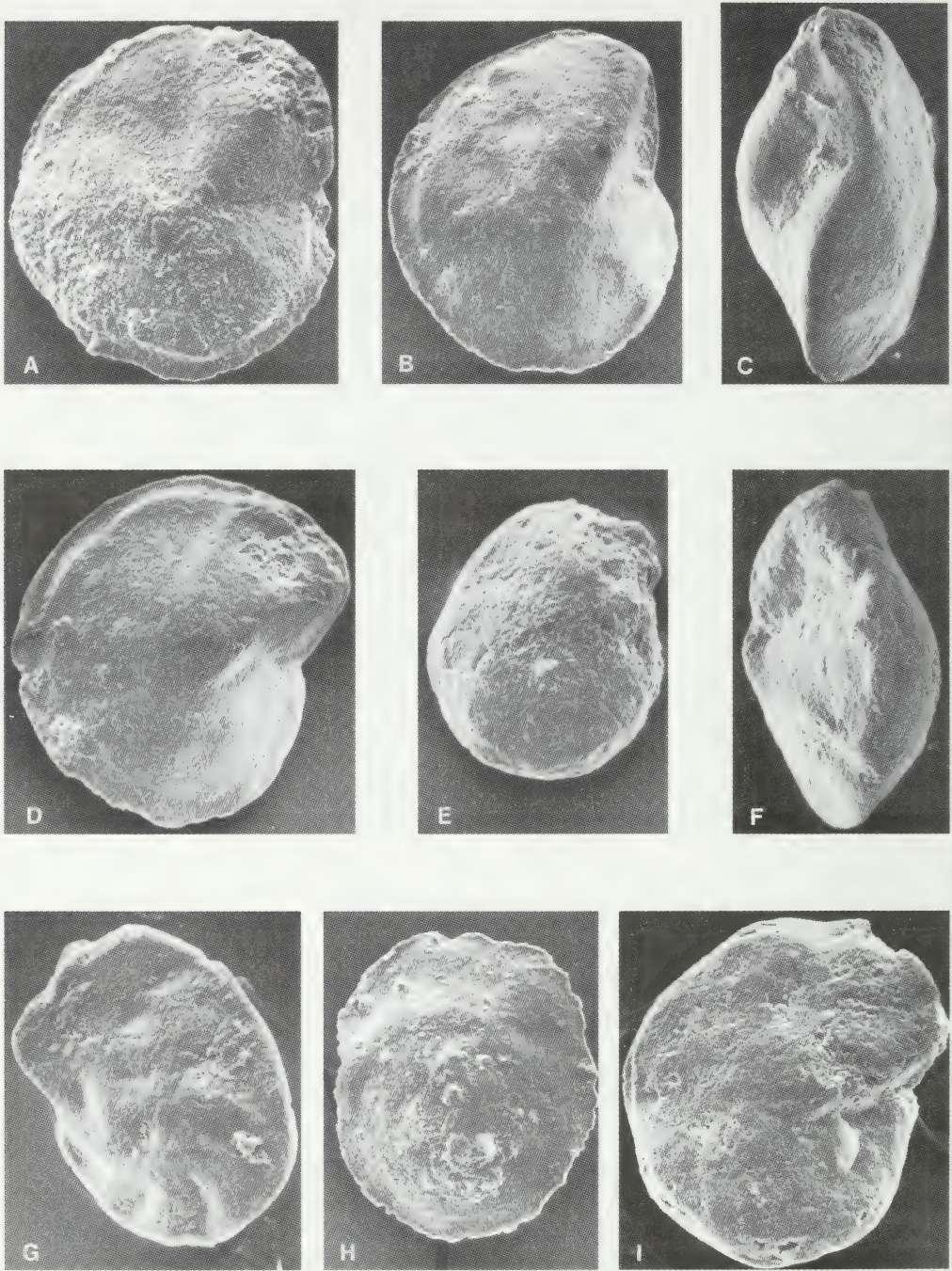


Figure 70.



*Epistomina caracolla* (non Roemer): McLachlan *et al.*, 1976a: 336, fig. 17, (nos 18–19); 1976b: 359, fig. 13 (nos 13–16). Masiuk & Viña, 1986a: 18, pl. 1 (figs 8a–b, 9). Jones & Wonders, 1992: 564, pl. 2 (fig. 22).

see *Hoeglundina caracolla* (Roemer). Hart *et al.*, 1981: 204, pl. 7.16 (figs 10–12).

see *Epistomina caracolla caracolla* (Roemer). Malumíán & Nañez, 1983: 387, pl. 3 (figs 1–5).

### Remarks

Examination of tests of *Epistomina caracolla* from the Hauterivian and Barremian of the Speeton Clay of the Yorkshire coast, England (Fig. 69B–D), as well as other authors' scanning electron microscope photographs (Hart *et al.* 1981; Lott *et al.* 1986), indicates that north-west European forms of this species are much more massively constructed, more strongly biconvex, and with significantly more chambers in the final whorl (usually 9–11) than is typical in South African specimens referred to this species. The limits of Roemer's species have become greatly widened, both in the Northern and Southern hemispheres, by the inclusion under this name of a considerable variety of forms with smooth-walled tests, perhaps with weakly raised, limbate sutures, from the Early Cretaceous. The name has tended to become a catch-all for most morphologies of this type. If the north-west European tests are considered as *Epistomina caracolla* *sensu stricto*, then it seems probable that the South African specimens should be referred elsewhere, as the morphological ranges of the two groups are substantially different and do not overlap. However, there is no other appropriate available name that effectively encompasses their morphology. Since the Southern Hemisphere form clearly occupied a similar niche to *Epistomina caracolla* *s.s.* of the Northern Hemisphere, and often occurs in floods like its northern counterpart, the name *Epistomina caracolla* *s.l.* has been used here for the austral group. Morphometric analysis of the group (*s.s.* and *s.l.*) on a fine scale is probably the only means of separating the many lineages of this complex, little-studied plexus.

An attempt has been made here to show a range of *Epistomina caracolla* *s.l.* tests from throughout the Sundays River Formation. However, they tend to be poorly endowed with surface features, and the resulting scanning electron microscope photographs are frequently rather bland, although better illustrations, using light microscope photography or drawings, are difficult to obtain without a confusion of internal and external details, or a projection of internal details to the exterior, respectively. Hauterivian tests tend to be more strongly biconvex, especially ventrally, whereas Late Valanginian shells are generally

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Fig. 70 (see facing page). *Epistomina caracolla* (Roemer) *s.l.* A. SAM-PQ-MF1597, ventral view, AL 1/69, 1 540 feet (VI), F421.  $\times 132$ . B. SAM-PQ-MF1598, ventral view, AL 1/69, 1 930 feet (VII), F467.  $\times 112$ . C. SAM-PQ-MF1599, side view, AL 1/69, 1 930 feet (VII), F470.  $\times 115$ . D. SAM-PQ-MF1600, ventral view, AL 1/69, 1 960 feet (VII), F473.  $\times 101$ . E. SAM-PQ-MF1601, ventral view, AL 1/69, 2 360 feet (VIII), F501.  $\times 175$ . F. SAM-PQ-MF1602, side view, AL 1/69, 2 360 feet (VIII), F502.  $\times 160$ . G. SAM-PQ-MF1603, dorsal view, AL 1/69, 2 410 feet (VIII), F510.  $\times 145$ . H. SAM-PQ-MF1604, dorsal view, AL 1/69, 2 830 feet (IX), F524.  $\times 114$ . I. SAM-PQ-MF1605, ventral view, MV 1/79, 180–190 m (X), F607.  $\times 251$ .

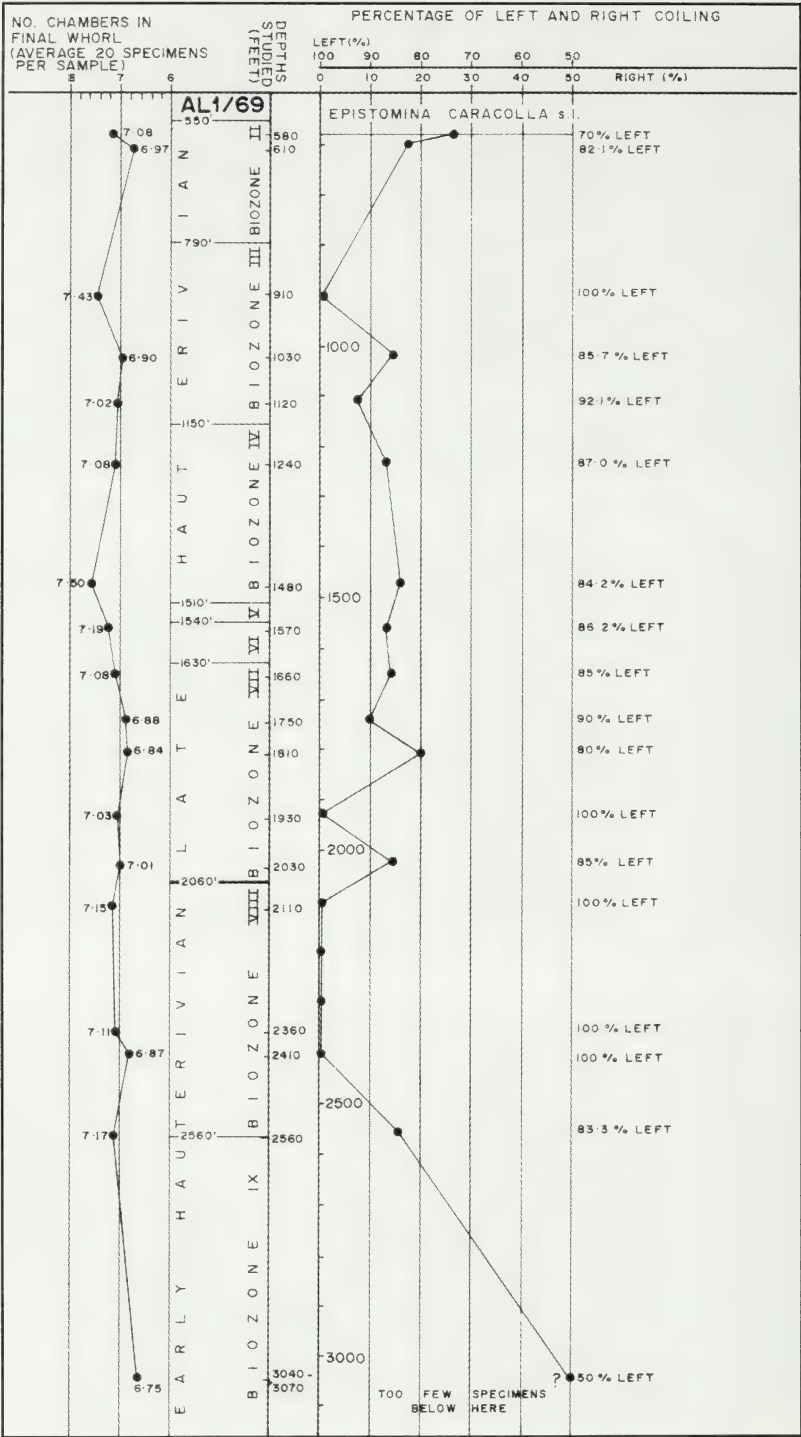


Figure 71.

Numbers of chambers in the final whorl and coiling direction in *Epistomina caracolla* (Roemer) s.l., in the Hauterivian of borehole AL 1/69 (A—see above) and the Late Valanginian to Early Hauterivian of borehole MV 1/79 (B—see alongside).

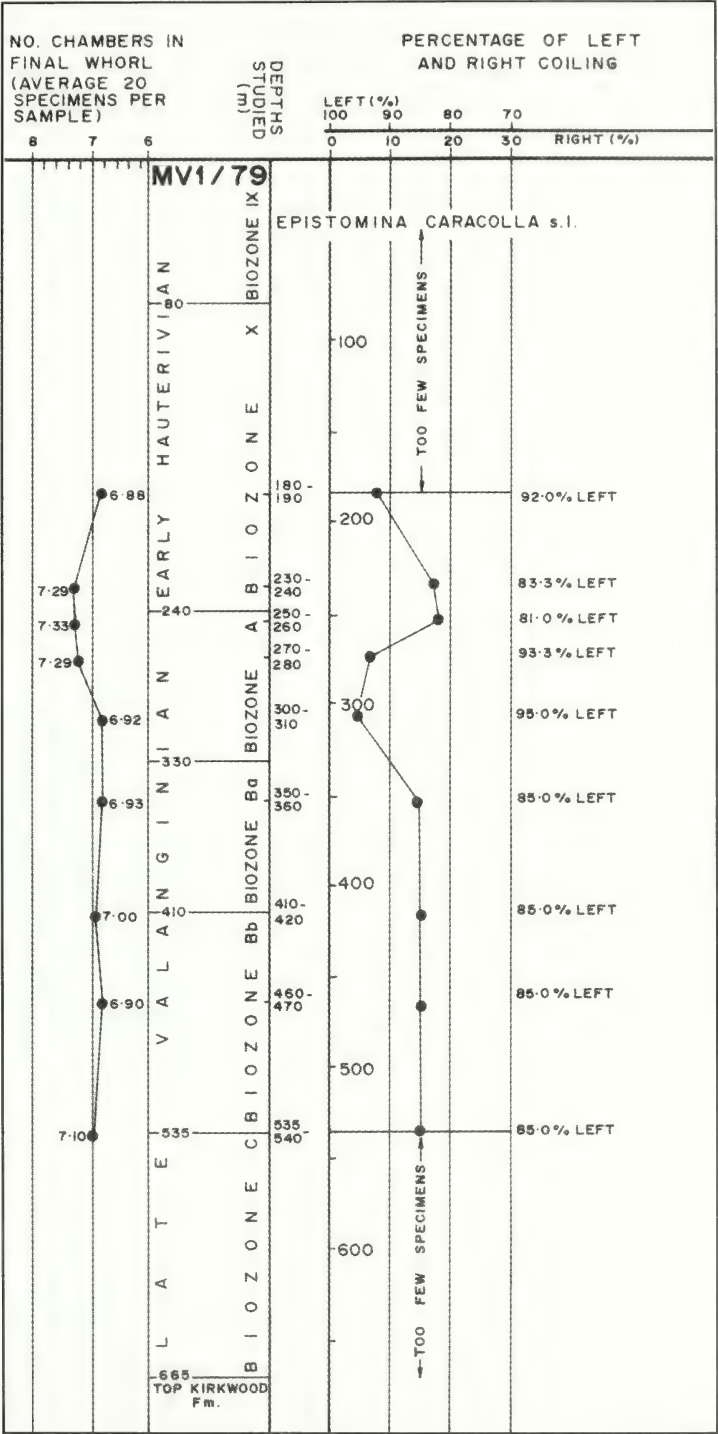


Figure 71 (CONTINUED).



more compressed, often with an almost bicarinate periphery angled on either side of the sealed marginal apertures. The distribution of *Epistomina caracolla* s.l. through the Sundays River Formation shows considerable fluctuations in abundance. The species is absent in Biozone D, is rare in Biozone C, but becomes abundant from the base of Biozone Bb to the top of Biozone A in the Late Valanginian, where the species predominates in most samples, almost to the exclusion of other species. The species is rare, but usually persistent, throughout the Early Hauterivian, and although more common in the Late Hauterivian and present in most samples, it remains a minor element of these nodosarid-dominated assemblages. This distribution through the Sundays River Formation tends to fade towards the margins of the basin, to the west, north and east, and is clearly best developed where middle- and outer-shelf environments prevailed.

Because of the frequency of *Epistomina caracolla* s.l. through the Sundays River Formation, tests were counted at regular intervals throughout, and the ratio of left to right coiled individuals determined. This technique was first attempted by Ohm (1968) on *Epistomina caracolla* s.s. of the Valanginian of north-west Germany. Numbers of chambers in the final whorl were also counted, using about twenty or twenty-five well-preserved tests per sample. In order to avoid contamination due to down-hole caving, the Hauterivian (Biozones I to base IX) of borehole AL 1/69 and the Late Valanginian and earliest Hauterivian (Biozones top X to C) of borehole MV 1/79 were studied (Fig. 71). No substantial changes in either parameter have been recognized throughout the Sundays River Formation, although minor fluctuations do occur, which perhaps may be of stratigraphic value. However, the generally poor quality of adjacent cuttings boreholes, and the more erratic distribution of the species through cored borehole CO 1/67, hinders any attempts at correlating these features on a wider scale. Most assemblages contain 90 to 95 per cent sinistrally coiled tests with from six-and-a-half to seven-and-a-half chambers in the final whorl.

Variation in the morphology of the *Epistomina caracolla* s.l. tests can be seen in the test periphery, which may be sub-angular to carinate, and occasionally serrated carinate (Fig. 70H). Sutures are generally flush to weakly depressed but, particularly in the Late Valanginian, shells with weakly raised sutures occur. Occasional examples feature irregular inverted L 'glyphs' on the dorsal side of the chambers in the final whorl (Fig. 72E). The ventral umbilicus is always flush, infilled and unornamented.

Tests of *Epistomina caracolla* s.l. illustrated by Malumián and Nañez (1983) from the Barremian Río Mayer Formation of Santa Cruz Province, Argentina, are very different from those of the Sundays River Formation, notably in the sutural ribs on both ventral and dorsal sides of the test. The whole assemblage detailed by these authors, with the dominance of suturally ribbed *Epistomina caracolla* s.l., closely resembles Early Barremian assemblages from poorly oxygenated, organically enriched, high-gamma, grey or black shelf claystones in the Bredasdorp, Pletmos and Zululand basins: these assemblages remain to be described.

The only illustrated tests from elsewhere with which our specimens compare at all closely in their finer morphological features are those of Masiuk & Viña (1986a), from the Late Hauterivian portion of the Upper Agrio Formation, Neuquén, Argentina. These tests

appear to be plano-convex or biconvex, with the dorsal side strongly convex and the ventral side weakly so, the final whorl displays 8, rarely 6 chambers, and all tests are sinistrally coiled, with a weakly polygonal and carinate periphery.

### Occurrence

Described from the Early Cretaceous of northern Germany (Roemer 1841). Later records include: Early Berriasian to mid-Barremian of the Speeton Clay sequence, north-eastern England (Hart *et al.* 1981; Lott *et al.* 1986); Late Valanginian to Early Barremian of north-west Germany (Bartenstein & Bettenstaedt 1962); Early Berriasian to Early Barremian off the south coast of South Africa, including the records of McLachlan *et al.* (1976a, 1976b); and Late Hauterivian Upper Agrio Formation, Neuquén, Argentina (Masiuk & Viña 1986a).

### Stratigraphic range in the Sundays River Formation

Late Valanginian to Late Hauterivian (Biozones C to I). Widespread, but absent in hypersaline conditions along the northern fringe of the Sundays River Formation.

Family **Ceratobuliminidae** Cushman, 1927

Subfamily Reinholdellinae Seiglie & Bermúdez, 1965

Genus *Reinholdella* Brotzen, 1948

*Reinholdella valendisensis* (Bartenstein & Brand, 1951)

Figs 72F–I, 73A–F

*Conorbis valendisensis* Bartenstein & Brand, 1951: 326, pl. 11 (figs 321a–c, 322a–c, 342–343).

Beer, 1970: 18, pl. 3 (fig. 7a–c).

*Reinholdella valendisensis* (Bartenstein & Brand). McLachlan *et al.*, 1976a: 336, fig. 17 (nos 22–23); 1976b: 359, fig. 13 (nos 22–23), *non* fig. 14 (nos 1–2)).

*Conorboides valendisensis* (Bartenstein & Brand). Ascoli, 1976: 684, pl. 3 (fig. 2a–c) (see also pl. 14 (fig. h)). Bartenstein, 1976b: 256, fig. 1.

see *Conorboides valendisensis* (Bartenstein & Brand). Hart *et al.*, 1981: 186, pl. 7.7 (figs 6–8).

Lofaldli & Thusu, 1979: 420, pl. 47 (fig. 27). Jones & Wonders, 1992: 564, pl. 2 (fig. 21).

### Remarks

More detailed examination of the PB–A1 borehole section subsequent to the work of McLachlan *et al.* (1976b), together with study of many additional borehole sections in the Pletmos, Gamtoos and Algoa basins, has shown that tests of the '*Reinholdella valendisensis* group' range for a longer period of time than was thought. They first appear in the Portlandian in abundance in parts of the offshore Algoa Basin, disappear in the Early Berriasian, then reappear in small numbers in the Late Berriasian and Early Valanginian. They are again in abundance in the Late Valanginian, are absent in the earliest Hauterivian, present locally in the mid- and later Hauterivian, and occur finally in the mid-Barremian.

This group has been divided into five taxa, all of which are clearly closely related. The



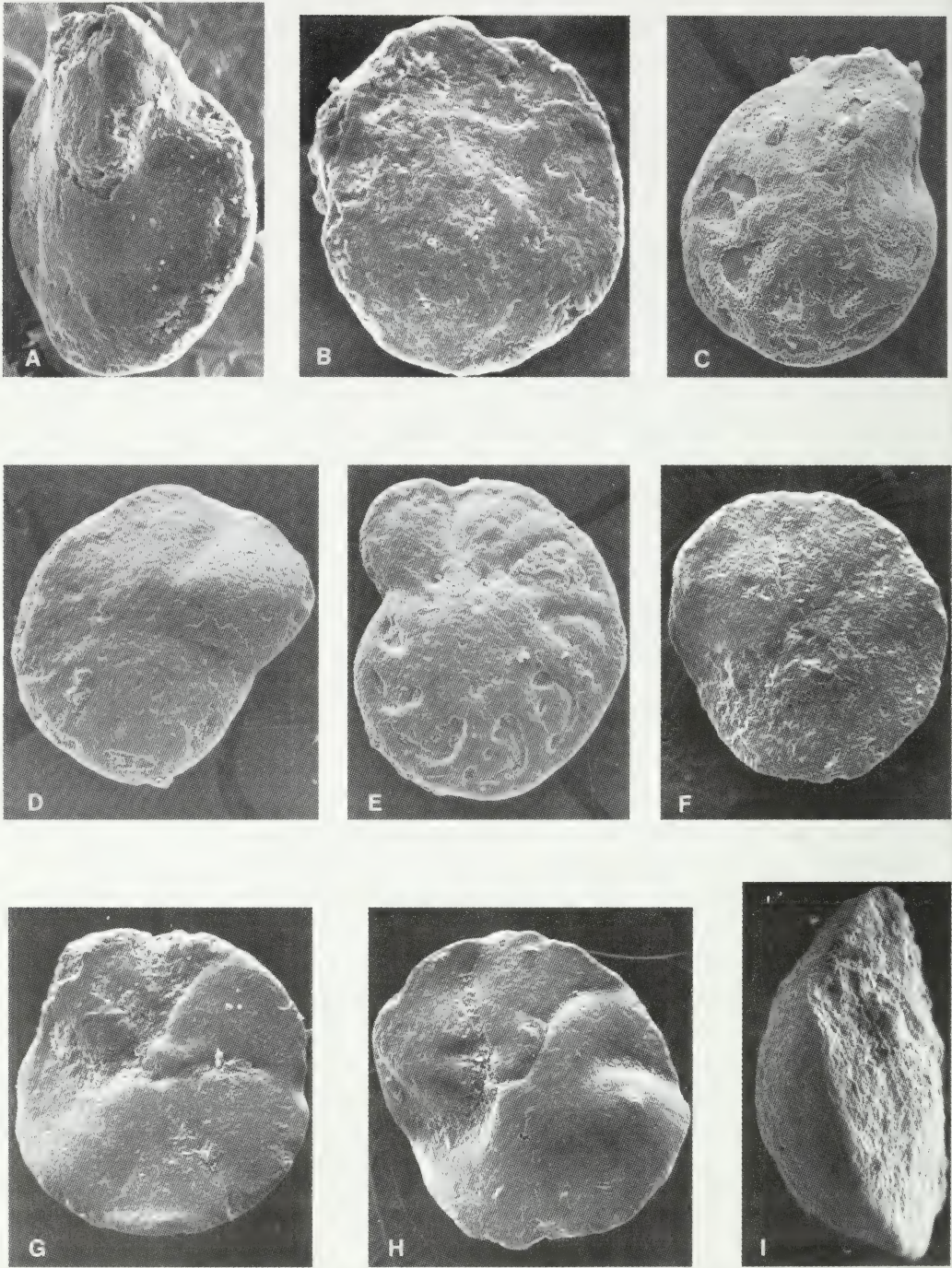


Figure 72.



earliest and latest of the five, found in the Portlandian of the offshore Algoa Basin, and in the Barremian of the Bredasdorp Basin and in Zululand, are not considered further here. Comments on the remaining three, given the names *R. valendisensis*, *R. v. plettenbergia* subsp. nov. and *R. platterugensis* sp. nov., follow below.

It has proved difficult to determine if the South African specimens from the Late Berriasian to the top of the Valanginian are conspecific with Bartenstein & Brand's species from north-west Germany, and to which genus these forms should be referred. *Conorboides* (a replacement name for *Conorbis* Hofker) has been used for this species by Northern Hemisphere workers, but the presence of a slightly convex ventral side, often with an umbilical plug, and an extra-umbilical foramen and a possible similarly placed aperture too, are not typical of this genus (see Loeblich & Tappan 1964: C769). These forms seem to compare more closely with the genus *Reinholdella* in their external morphology. The original description of *Conorbis valendisensis* by Bartenstein & Brand (1951) gave no details on the structures within the chamber cavities, but the style of recess development along the ultimate suture in their illustrations is very reminiscent of *Reinholdella* species. No indication is made as to whether the sutural recess remains evident on earlier sutures, or whether it is absent, or concealed by the calcification developed over the ventral side of the test. Subsequent scanning electron microscope photographs of this species provide little additional data, because of poor preservation (Ascoli 1976) or damage (Hart *et al.* 1981). Until subsequent, more detailed work on European *Reinholdella valendisensis* is completed, some doubt remains as to whether the South African Berriasian and Valanginian tests are truly referable to that species.

Late Valanginian tests from the Sundays River Formation assigned to *R. valendisensis* possess the following features: almost all tests encountered are dextrally coiled (as are all illustrated Northern Hemisphere tests), the test is plano-convex, with the dorsal side strongly convex and the ventral side usually weakly convex and somewhat thickened or 'calcified'; test periphery circular, occasionally weakly lobate in the final part; in cross-section test margin is rounded in juveniles, becoming sub-angular in adults. Chambers arranged in a high trochospiral coil, with from six to seven-and-a-half in the final whorl. Dorsal sutures generally distinct in the later part of the test, weakly raised, limbate, curved to almost straight, oblique; ventral sutures initially indistinct, generally with the last two or three becoming distinct, radiate, weakly depressed, curved or sinuous. About one-third to half-way along their length from the umbilicus, all ventral sutures

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Fig. 72 (see facing page). A–E. *Epistomina caracolla* (Roemer) s.l. A. SAM-PQ-MF1606, oblique side view, MV 1/79, 180–190 m (X), F609.  $\times 240$ . B. SAM-PQ-MF1607, dorsal view, MV 1/79, 180–190 m (X), F608.  $\times 180$ . C. SAM-PQ-MF1608, ventral view, Uitenhage to Graaff-Reinet Road outcrop sample 11464 (Bb), F66.  $\times 114$ . D. SAM-PQ-MF1609, ventral view, Uitenhage to Graaff-Reinet Road outcrop sample 11464 (Bb), F67.  $\times 114$ . E. SAM-PQ-MF1610, dorsal view, Uitenhage to Graaff-Reinet Road outcrop sample 11464 (Bb), F68.  $\times 120$ . F–I. *Reinholdella valendisensis* (Bartenstein & Brand), adult tests. F. SAM-PQ-MF1611, ventral view, MV 1/79, 250–260 m (A), F630.  $\times 80$ . G. SAM-PQ-MF1612, ventral view, MV 1/79, 330–340 m (Ba), F656.  $\times 89$ . H. SAM-PQ-MF1613, ventral view, MV 1/79, 270–280 m (A), F653.  $\times 69$ . I. SAM-PQ-MF1614, side view, MV 1/79, 250–260 m (A), F632.  $\times 88$ .

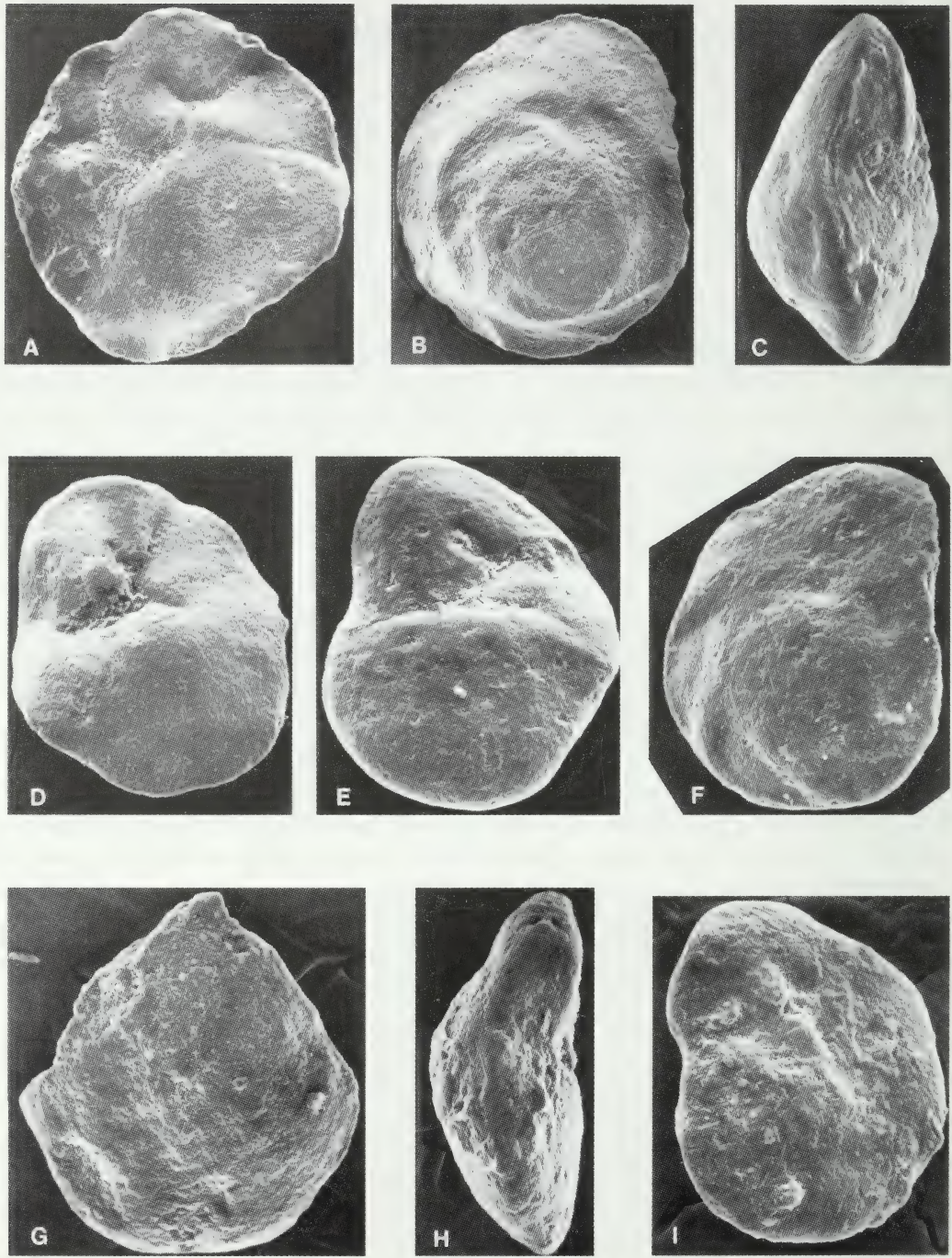


Figure 73.



feature a narrow indentation into the following chamber, although this is only clear in the early sutures when tests are moistened. The aperture is interio-marginal, umbilical to extra-umbilical, at the base of the terminal face of the final chamber, although this is rarely clearly evident in Sundays River Formation tests. The umbilicus is almost entirely infilled with a solid plug of shell, although the size of the plug and its prominence at the surface vary. Apart from the limbate dorsal sutures, the exterior of the test is smooth and unornamented. A partition is developed within each chamber cavity, associated with the externally visible sutural indentations. Unfortunately, all tests of *R. valendisensis* from the Sundays River Formation are calcite or pyrite infilled, and it has not yet proved possible to establish the structure of the partition. However, on tests with the final chamber broken away, a fragment of the base of the partition is evident along the inner side of the ovate foramen, extending from near the floor of the chamber up to, and joining with the roof (that is, the ventral test wall).

Examination of assemblages of *R. valendisensis* from the Sundays River Formation indicates that there is a marked difference in morphology between the juvenile and adult tests. Juveniles (Fig. 73C–F) are characterized by lower, more nearly biconvex tests with broadly rounded margins. Adults (Figs 72F–I, 73A–B) develop rather more bowl-shaped, almost plano-convex tests with a high trochospire and subangular margins.

### Occurrence

First described from the middle Valanginian of north-west Germany (Bartenstein & Brand 1951). Other records include: middle Valanginian (Khan 1962) and Berriasian to latest Valanginian (Fletcher 1973; Hart *et al.* 1981) of the Speeton Clay sequence, north-east England; Berriasian to Valanginian of eastern offshore Canada (Ascoli 1976; Bartenstein 1976b), although later work (Jansa *et al.* 1980) indicates the species ranges to late in the Hauterivian; Late Valanginian Biozone B of the Mngazana Basin, Transkei (McLachlan *et al.* 1976a); and the earliest Late Valanginian (Biozone D) Brenton Formation and Late Valanginian (Biozones B to top A) of Pletmos Basin borehole PB–A1 (McLachlan *et al.* 1976b). Note that the range given for this species by McLachlan *et al.* (1976b, fig. 10) is incorrect; its first down-hole appearance coincides with that of *R. hofkeri* (Bartenstein & Brand).

*Reinholdella valendisensis* occurs extensively in the offshore Pletmos, Gamtoos and Algoa basins off the south coast of South Africa. It appears in small numbers in the Late

Fig. 73 (see facing page). A–F. *Reinholdella valendisensis* (Bartenstein & Brand). A–B. Adult tests. A. SAM–PQ–MF1615, ventral view, MV 1/79, 260–270 m (A), F635.  $\times 92$ . B. SAM–PQ–MF1616, dorsal view, MV 1/79, 260–270 m (A), F636.  $\times 72$ . C–F. Juveniles. C. SAM–PQ–MF1617, side view, MV 1/79, 260–270 m (A), F641.  $\times 215$ . D. SAM–PQ–MF1618, ventral view, MV 1/79, 260–270 m (A), F639.  $\times 146$ . E. SAM–PQ–MF1619, ventral view, MV 1/79, 260–270 m (A), F638.  $\times 222$ . F. SAM–PQ–MF1620, dorsal view, MV 1/79, 260–270 m (A), F651.  $\times 250$ . G–I. *Reinholdella* sp. D. G. SAM–PQ–MF1621, dorsal view, AL 1/69, 1 240 feet (IV), F352.  $\times 251$ . H. SAM–PQ–MF1622, side view, AL 1/69, 1 240 feet (IV), F353.  $\times 300$ . I. SAM–PQ–MF1623, ventral view, AL 1/69, 1 240 feet (IV), F351.  $\times 265$ .



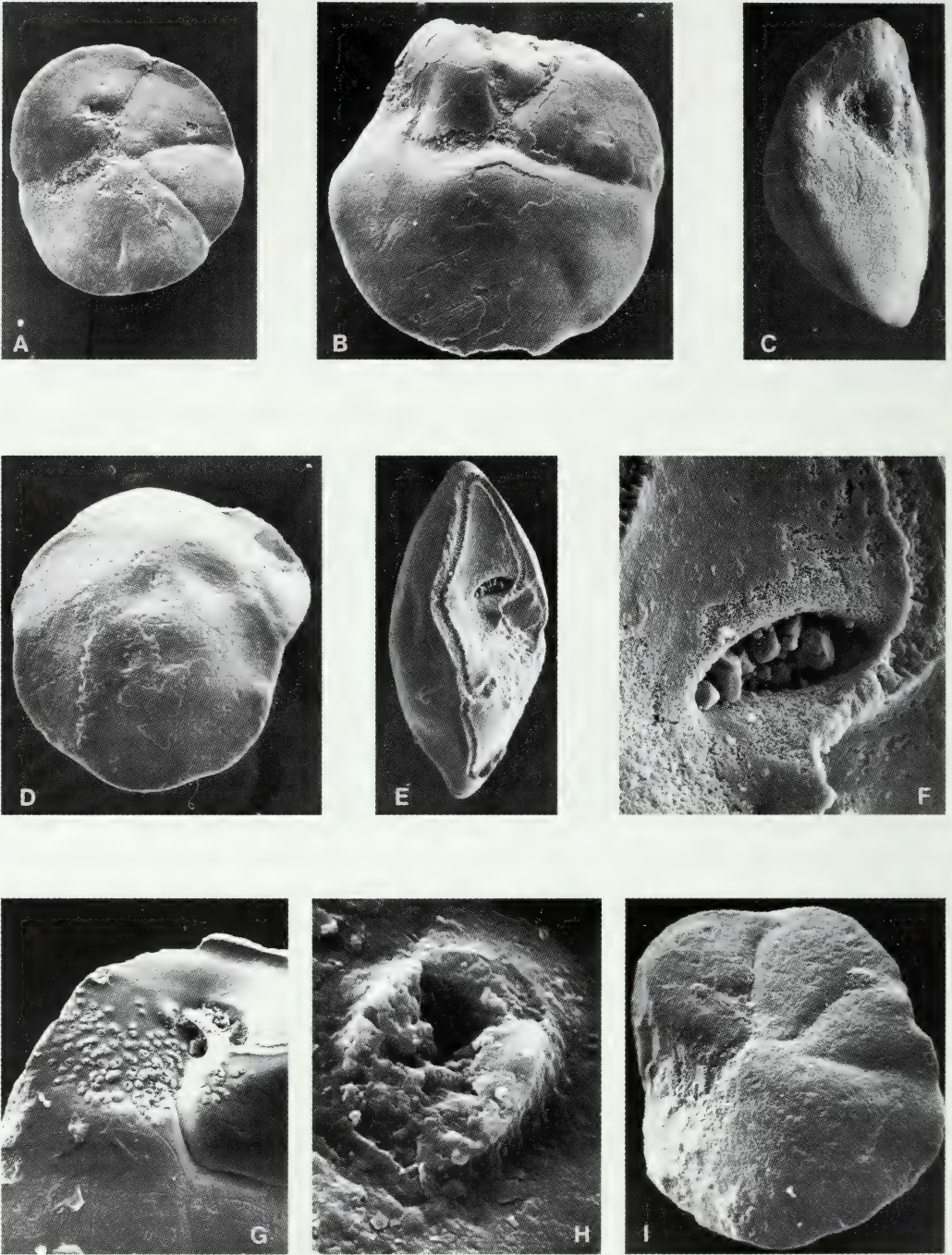


Figure 74.

Berriasian, ranges similarly through the Early Valanginian, and becomes abundant in the Late Valanginian. Because of major facies changes at the level of the seismic 1At1 unconformity, lying at a level very near the top of Biozone B, *R. valendisensis* is often missing in the latest Valanginian in these three basins. Where shallower marine conditions prevailed across the 1At1 unconformity, *R. valendisensis* ranges up to the top of the Valanginian in some numbers, as is the case in the Sundays River Formation.

#### *Stratigraphic range in the Sundays River Formation*

Base of Biozone Bb to the top of Biozone A, Late Valanginian. Depositional environments in Biozones C and D appear to have been too shallow for the species' preferences, and it is not found in the estuarine and hyposaline facies in the northern Algoa Basin. In Biozone A, numbers are very variable in different borehole sections: the species is always more common in clayey sequences than in silty or sandy ones.

#### *Reinholdella* sp. D

Figs 73G–I

#### *Remarks*

This is one of several small-sized *Reinholdella* species recognized over short intervals in the Late Hauterivian. Only seven specimens of *Reinholdella* sp. D have been found, six of which are from the middle of Biozone IV in borehole AL 1/69 and the remaining one from Colchester Cliff outcrop (also Biozone IV). Tests are low trochospiral, compressed, with about seven chambers in the final whorl and a sub-rounded to broadly rounded test periphery. Sutures on both ventral and dorsal sides are flush: oblique on the dorsal, radiate on the ventral.

Tests of this and the other rare species of *Reinholdella* (species A to C), although confined to short stratigraphic intervals, are usually poorly preserved and are not widely distributed, and until now have thus proved of little use in correlation studies. For these reasons, the even rarer *Reinholdella* sp. A and sp. B are not discussed further in the present work.

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Fig. 74 (see facing page). A–H. *Reinholdella platterugensis* sp. nov. A. Holotype, SAM–PQ–MF1624, ventral view, AL 1/69, 460 feet (I), F102.  $\times 56$ . B. Paratype, SAM–PQ–MF1625, ventral view, AL 1/69, 370 feet (I), F44.  $\times 129$ . C. Paratype, SAM–PQ–MF1626, side view, AL 1/69, 400 feet (I), F55.  $\times 84$ . D. Paratype, SAM–PQ–MF1627, dorsal view, AL 1/69, 370 feet (I), F45.  $\times 148$ . E. Paratype, SAM–PQ–MF1628, side view, AL 1/69, 400 feet (I), F53.  $\times 129$ . F. SAM–PQ–MF1628, close-up of foraminal area of E, F54.  $\times 646$ . G. Paratype, SAM–PQ–MF1629, showing tubercles on floor of final chamber, AL 1/69, 790 feet (III), F222.  $\times 227$ . H. SAM–PQ–MF1629, close-up of perforated tubercle of G, F223.  $\times 5915$ . I. *Reinholdella valendisensis plettenbergia* subsp. nov. Paratype, SAM–PQ–MF1630, ventral view, AL 1/69, 2 470 feet (VIII), F517.  $\times 86$ .







*Etymology*

Named for its presence in the highest Sundays River Formation of borehole AL 1/69, which was drilled on the lands of the old farm Platterug ('Flat Ridge').

*Material*

*Holotype* (Fig. 74A). MF1624, SOEKOR negative F102.

*Paratypes* (Figs 74B–H). MF1625 to MF1629, five specimens, SOEKOR negatives F44, F55, F45, F53/F54, and F222/F223.

*Stratum typicum*

Biozone I, Late Hauterivian, Sundays River Formation.

*Locus typicus*

Borehole AL 1/69, 460 feet.

*Description*

Test plano-convex to biconvex, with ventral side less convex, dorsal side more strongly convex. Test periphery circular in outline, acutely rounded to sub-rounded in cross-section; never carinate, but showing a faint thickening around the dorsal margin. Almost all tests are dextrally coiled. Chambers arranged in a moderately high trochospiral coil, with six or seven in the final whorl. Chambers wedge-shaped in ventral view, semicircular to lunate in dorsal view. Last-formed one or two chambers weakly inflated, especially on the ventral side. Sutures indistinct to distinct; on the ventral side initially flush, later weakly depressed, radiate and slightly curved; marked at one-third of their length from the umbilicus by a distinct, perpendicular incision into the following chamber: incision visible on the final few sutures, but is present on them all, previous ones apparently being secondarily infilled. Dorsal sutures initially flush or weakly raised, limbate, becoming weakly raised, oblique and gently curved. Aperture interio-marginal, a low elongate slit developed from the final sutural incision, past the umbilicus to an extra-umbilical position some distance from the test periphery. The upper margin of the aperture is bordered by a thin, blade-like, slightly out-turned lip. Umbilicus infilled by a low, rather poorly developed swelling.

Within the chamber lumen a short partition is developed from the inner, umbilical side of the foramen, which thins and declines rapidly in height as it extends and curves into the chamber cavity. The partition thus partly separates the main body of the chamber cavity with the foramen from a small, umbilically located portion with the aperture; the addition of a further chamber seals most or all of the previous aperture. It is clear that the elongate-ovate foramen must be secondarily formed at the time of adding the next chamber, since its shape and areal position are radically different from the construction and location of the aperture. The floor of the inner portion of the final chamber, between the partition and the aperture is secondarily ornamented by up to a hundred or so small rounded-topped tubercles or crater-like prominences. These may also be present in small numbers above the foramen, close to the ventral side of the test. This internal

ornamentation is unique to the final chamber, and is removed from the floors of earlier chambers. Surface of test smooth, unornamented; no secondary calcification on the ventral side.

#### Remarks

*Reinholdella platterugensis* is clearly closely related to *R. valendisensis* (Bartenstein & Brand) as here understood, but it differs in a number of respects. Adult tests of *R. platterugensis* are never so strongly convex on the dorsal side, being generally more nearly biconvex; dorsal sutures are not as raised nor as limbate; the test periphery is acutely rounded rather than sub-angular; the secondary thickening of the ventral surface does not occur; and there are tuberculations within the final chamber. However, similar tuberculations do occur in the Early Hauterivian *R. valendisensis plettenbergia* subsp. nov. (see below).

*Reinholdella platterugensis* shows little similarity to Jurassic species of the genus. *Reinholdella dreheri* (Bartenstein in Bartenstein & Brand 1937) exhibits a broad, rounded test periphery; *R. media* (Kaptarenko-Chernousova) is similar in outline but displays a distinctly larger and more prominent umbilical boss (Kaptarenko-Chernousova 1959); *R. crebra* Pazdro (1969) possesses fewer chambers, about five, in the final whorl, and the coiling is generally sinistral, according to Coleman (1981).

Coiling of *R. platterugensis* tests (Fig. 75) in the topmost part of borehole AL 1/69 is predominantly dextral, with 6–7 chambers in the final whorl. No clear trends can be seen in AL 1/69, and the poor quality of KE 1/71 section—the only other one in which this species occurs—precludes identification of changes in these two test characteristics that may be of stratigraphic value.

#### Stratigraphic range in the Sundays River Formation

Restricted to the later Late Hauterivian (Biozones II and I). This species has as yet not been found offshore in time-equivalent strata in the Pletmos, Gamtoos or southern Algoa basins, partly because of the widespread erosion of Hauterivian rocks during the latest Hauterivian to earliest Barremian, and partly because of the rather narrow continental shelf that, in combination with anoxic slope facies at this time, restricted the distribution of *R. platterugensis* considerably, when compared with the widespread Late Valanginian distribution of *R. valendisensis*. In unpublished reports on the foraminifera of the Sundays River Formation, onshore Algoa Basin, this distinctive species has been identified as *Lamarckina* sp. (Beer 1973), *Pseudolamarckina* cf. *P. rjaesanensis* (Venter 1971) and *Reinholdella* sp. and *R. valendisensis* (Bagnall *et al.* 1971d, 1972c).

*Reinholdella valendisensis* (Bartenstein & Brand) *plettenbergia* subsp. nov.

Fig. 74I

*Reinholdella valendisensis* (non Bartenstein & Brand): McLachlan *et al.*, 1976b: 359, fig. 14 (nos 1–2), non fig. 13 (nos 22–23).

*Remarks*

Tests of *Reinholdella valendisensis plettenbergia* differ from *R. valendisensis valendisensis* in South Africa in their lower umbilical filling and the strong tuberculate ornamentation within the final chamber. However, in the general test morphology, the nature of the dorsal and ventral surfaces, the sutures, chamber shape and trochospire height, no distinct differences between the two can be ascertained.

*Reinholdella valendisensis plettenbergia* occurs only in small numbers in the northern Algoa Basin, in the most distal borehole sections, especially AL 1/69. Only a few tests are sufficiently well preserved to merit photography. However, preservation is very much better in Pletmos Basin borehole PB-A1, and the test illustrated by McLachlan *et al.* (1976b, fig. 14 (no. 2)) is designated the holotype, deriving from 1 260 feet in that borehole, from high in Biozone IX. The subspecies is known from a number of other offshore boreholes of the Pletmos and Gamtoos basins. Its stratigraphic extent in PB-A1 and in the Sundays River Formation in AL 1/69 is from late in Biozone IX to early in Biozone VIII in the Early Hauterivian. It appears to range into deeper waters (upper continental slope) than is typical for the other species of *Reinholdella* from the Valanginian and Hauterivian rocks of South Africa.

The subspecies is named for its first occurrence in borehole PB-A1, sited just off the coast from Plettenberg Bay (adjective).

*Reinholdella* sp. C

## Fig. 76A

*Remarks*

Four specimens, most of which are damaged. Tests are relatively small for *Reinholdella*, and with their rather inflated chambers, show some similarity to *R. hofkeri* (Bartenstein & Brand, 1951). They differ, however, in their angled test periphery. The dorsal side is more strongly convex than the ventral. See also *Reinholdella* sp. D.

*Stratigraphic range in the Sundays River Formation*

Restricted to one horizon in the middle of Biozone III, Late Hauterivian. Too few specimens occur for this species to be considered stratigraphically significant at present.

*Reinholdella hofkeri* (Bartenstein & Brand, 1951)

## Figs 76B–G

*Conorbis hofkeri* Bartenstein & Brand, 1951: 325, pl. 11 (fig. 320a–c).

*Conorboides hofkeri* (Bartenstein & Brand). Bartenstein, 1976b: 256 fig. 1. Ascoli, 1976: 722 (fig. 27).

*Reinholdella hofkeri* (Bartenstein & Brand). McLachlan *et al.*, 1976a: 336, fig. 17 (nos 20–21); 1976b: 361, fig. 14 (nos 3–4). Masiuk & Viña, 1986a: 20, pl. 1 (fig. 7).

?*Reinholdella* sp. aff. *R. hofkeri* (Bartenstein & Brand). Masiuk & Viña, 1986a: 21, pl. 1 (fig. 6).



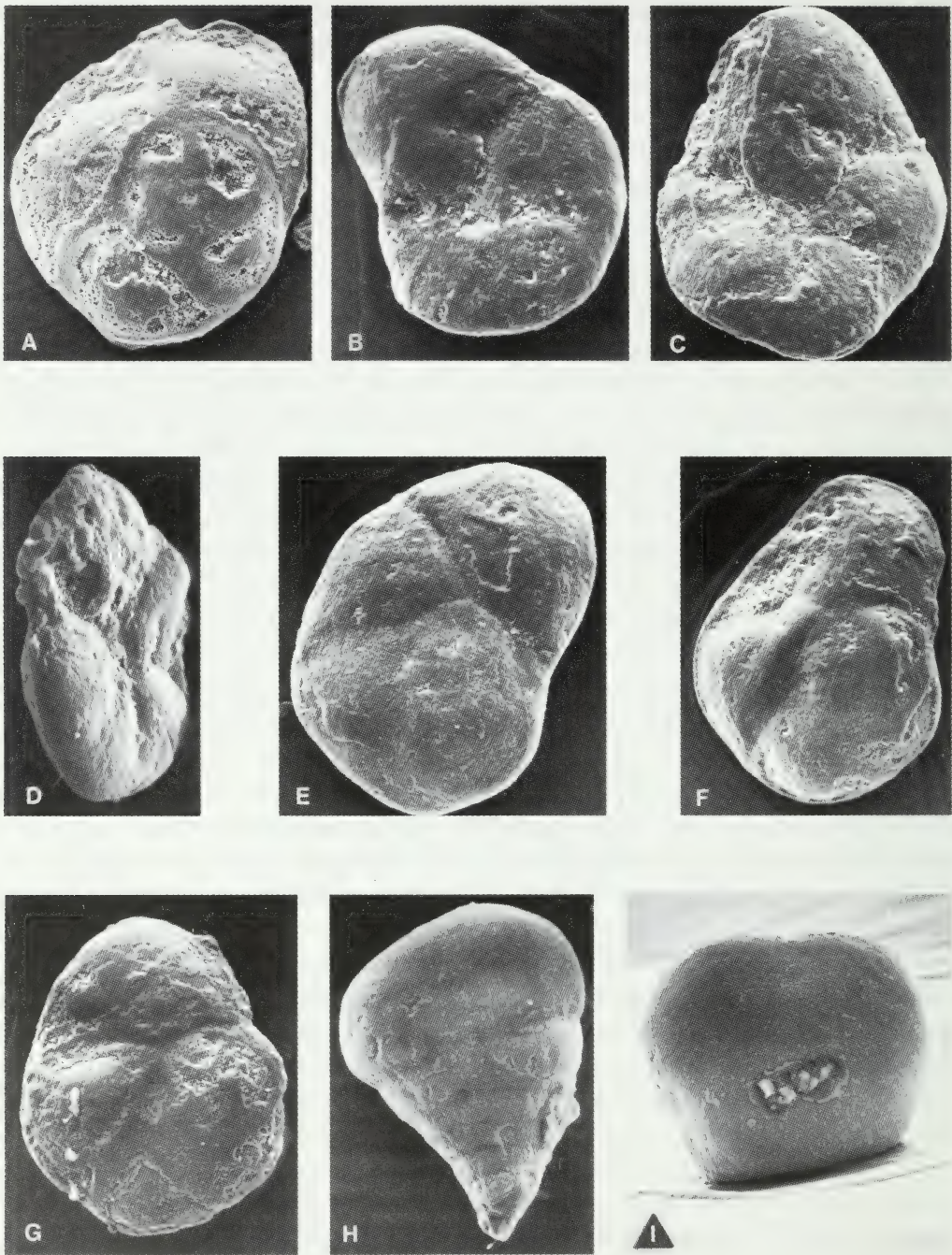


Figure 76.

### Remarks

Tests from South Africa possess peripheries that are rather more rounded in cross-section than the somewhat angled periphery of the holotype figured by Bartenstein & Brand (1951). As with the other species of *Reinholdella* discussed here, the sutural incisions projecting into the following chamber on the ventral side of the test can be seen on all of the sutures of the final whorl, although the earlier ones are only evident if the test is moistened, and appear to have been secondarily infilled. From the presence of the incisions and the umbilical to extra-umbilical aperture, this species seems better referred to *Reinholdella* than *Conorboides*.

It is felt that insufficient differences exist between the tests referred by Masiuk & Viña (1986a) to *R. hofkeri* and those referred to ?*Reinholdella* sp. aff. *R. hofkeri* from the Late Hauterivian part of the Agrio Formation. The height of the trochospire, the degree of inflation of the final chambers and the corresponding depression of the sutures all display variation in the present material, some of which is doubtless due to distortion of tests induced by compaction of the host rock. Thus both of the Argentinian tests (only dorsal views are illustrated) seem to fall within the morphological range of the species, as understood in South Africa.

Because of the generally greater depth of burial of the lower Sundays River Formation beds, tests of *R. hofkeri* from the Algoa Basin are not as well preserved as those from borehole PB-A1 (McLachlan *et al.* 1976b). Most examples are juveniles.

### Occurrence

Originally described from the Late Valanginian of north-west Germany (Bartenstein & Brand 1951); Bartenstein (1976b) regarded its full range there as mid-Berriasian to Late Valanginian. Ascoli (1976) reported it to range from the Early Berriasian to the Late Barremian of the eastern continental margin of Canada. A closely comparable form, '?*Conorboides hofkeri*', was reported from the Late Hauterivian of the type Barremian section in France (Guillaume & Sigal 1965). Masiuk & Viña (1986a) obtained specimens from the Late Hauterivian part of the Agrio Formation, Neuquén, southern Argentina. In South Africa it has been recorded from Late Valanginian Biozone B of the Mngazana Basin (McLachlan *et al.* 1976a) and Late Valanginian Biozones B and A in Pletmos Basin borehole PB-A1 (McLachlan *et al.* 1976b). *Reinholdella hofkeri* occurs widely off the south coast of South Africa in the Pletmos, Gamtoos and offshore Algoa basins, where it is generally confined to Biozones C and B in the Late Valanginian, being absent in Biozone A because of low oxygen values on the sea-floor.

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Fig. 76 (see facing page). A. *Reinholdella* sp. C, SAM-PQ-MF1631, dorsal view, AL 1/69, 1 030 feet (III), F314.  $\times 124$ . B-G. *Reinholdella hofkeri* (Bartenstein & Brand). B. SAM-PQ-MF1632, ventral view, MV 1/79, 240-250 m (A), F617.  $\times 186$ . C. SAM-PQ-MF1633, ventral view, MV 1/79, 240-250 m (A), F616.  $\times 217$ . D. SAM-PQ-MF1634, side view, MV 1/79, 240-250 m (A), F621.  $\times 195$ . E. SAM-PQ-MF1635, dorsal view, MV 1/79, 240-250 m (A), F615.  $\times 230$ . F. SAM-PQ-MF1636, dorsal view, MV 1/79, 240-250 m (A), F620.  $\times 171$ . G. SAM-PQ-MF1637, dorsal view, MV 1/79, 240-250 m (A), F619.  $\times 158$ . H-I. ?*Colomia* sp. H. SAM-PQ-MF1638, side view, AL 1/69, 1 480 feet (IV), F384.  $\times 256$ . I. SAM-PQ-MF1638, apertural view of H, F392.  $\times 283$ .



*Stratigraphic range in the Sundays River Formation*

Confined to the Late Valanginian, from Biozone Bb to top Biozone A. There are one or two possible *in situ* records also in Biozone C. The species is absent in reduced salinity and other marginal marine environments, as well as in substantially reduced oxygen facies as seen in borehole CK 1/68.

Family **Robertinidae** Reuss, 1850

Genus *Colomia* Cushman & Bermúdez, 1948

?*Colomia* sp.

Figs 76H–I

*Remarks*

A single specimen with a test wall, although damaged, of the same visual type as *Reinholdella* and *Epistomina*, is very reminiscent of tests of *Colomia*. The shell consists of about seven uniserial, roughly rectilinear chambers. In apertural view the test is faintly trilobate in outline. The elongate opening with rounded ends, sited centrally on the terminal face, lacks the curved ends of the typical *Colomia* aperture.

The presence of the single poor test has precluded any attempt to confirm the wall as either aragonite or calcite, or to establish if the distinctive *Colomia* style of internal columella is developed between aperture and foramen in the final chamber cavity.

Other Early Cretaceous *Colomia* tests appear to be confined to the Albian Gault Clay (see *Bolivina subcretacea* Khan, 1950) of England, and the Late Aptian and Albian of South Africa (undescribed species), and earlier forms are not known. These Aptian–Albian species are predominantly biserial in chamber arrangement, becoming cuneate only in the latest part of the test, and never rectilinear and uniserial. Only in the Late Cretaceous do almost fully uniserial *Colomia* tests occur. This apparently entirely uniserial test from the Late Hauterivian, if referable to *Colomia*, is thus morphologically rather anomalous. There are perhaps relationships between Early Cretaceous (Aptian–Albian) *Colomia* and high-spined *Conorboides* with just over two chambers per whorl; different associations may exist for the Late Cretaceous rectilinear forms, and the genus may well be polyphyletic in origin.

## OTHER MICROFOSSIL GROUPS

*Radiolaria* (Figs 77A–J)

All Radiolaria obtained from the Sundays River Formation are preserved as pyrite casts, and show little of the original structure. Two major morphotypes can be recognized: spheres and conical segmented forms. The spherical forms may be referable to many genera, but the latter are probably assignable to *Dictyomitra* and its allies.

The spherical Radiolaria (Fig. 77A–E) casts are all composed of masses of minuscule pyrite crystals and/or microframiboidal pyrite spheres. They can be easily distinguished from non-radiolarian framiboidal pyrite masses by their near-spherical outline, which is rare in true framiboids, in the distinctly smaller size of the particles of pyrite that constitute



the cast, and in the presence of definite dimples in the surface of each visible particle (Fig. 77E). The last characteristic presumably reflects internal positive features of the original silica test. The dimples give the surface of the spherical cast an ornamentation rather reminiscent of a pineapple when viewed in close-up.

Radiolaria are confined to the most distal intersections through the Sundays River Formation, such as MV 1/79 and AL 1/69. They are never common, and are restricted to the clayier intervals of the sequence, principally between Biozone Bb to I, Late Valanginian to Late Hauterivian. The two major morphotypes show no restricted stratigraphic range within this interval.

It is probable that Radiolaria are more common in the sequence than is apparent. Their absence in a number of the distal boreholes is evidently due to differences in drilling and sample quality from hole to hole, a feature that has been discussed previously with regard to the foraminifera distributions. Their absence in nearly all outcrop samples, even those from distal localities, is due to a combination of their natural absence close to shore combined with the susceptibility of pyrite to percolating oxygenated groundwater.

A re-examination of samples from the Mngazana outcrop described by McLachlan *et al.* (1976a) has revealed far greater numbers and variety of Radiolaria than was originally thought, as noted previously. The sampled section is regarded as being of Biozone B, Late Valanginian age. It is clear this section is substantially richer in Radiolaria than any borehole interval or outcrop of equivalent age in the Pletmos, Gamtoos or Algoa basins off the south coast of South Africa, even allowing for some post-depositional destruction of tests. The Mngazana outcrop thus represents the locality most intimately influenced by true oceanic conditions yet known from the mid-Late Valanginian in South Africa.

#### *Bivalves (Fig. 78A) and gastropods*

Bivalve fragments are widespread throughout the Sundays River Formation, and in shelly sands or silts are especially common. The last comprehensive review of the Bivalvia of the Algoa Basin was by Kitchin (1908) and the trigonioids have been more recently re-appraised by Cooper (1991). In the borehole samples, because of the styles of drilling, substantial bivalve fragments are commonest in core samples, but even in the cuttings boreholes, scattered juvenile shells occur. These are usually those that are robustly constructed, such as the *Trigonia* illustrated. Gastropods also occur widely, but are seldom dominant, and none seen in the boreholes to date are particularly distinctive or stratigraphically useful; again, Kitchin (1908) last reviewed this group.

#### *Mysid statoliths (Figs 78B, D)*

Small golden-brown sub-spheres occur intermittently in small numbers through much of the sequence. All possess an indentation on one side, which exposes, to a variable degree, concentric layers. These spheres are considered to be mysid statoliths—‘stones’ of calcium fluorite secreted in the balance organs of the shrimp-like Mysidae (Crustacea). The most recent study and review of statoliths is by Voicu (1981), who has concentrated on those from the Miocene to Recent.

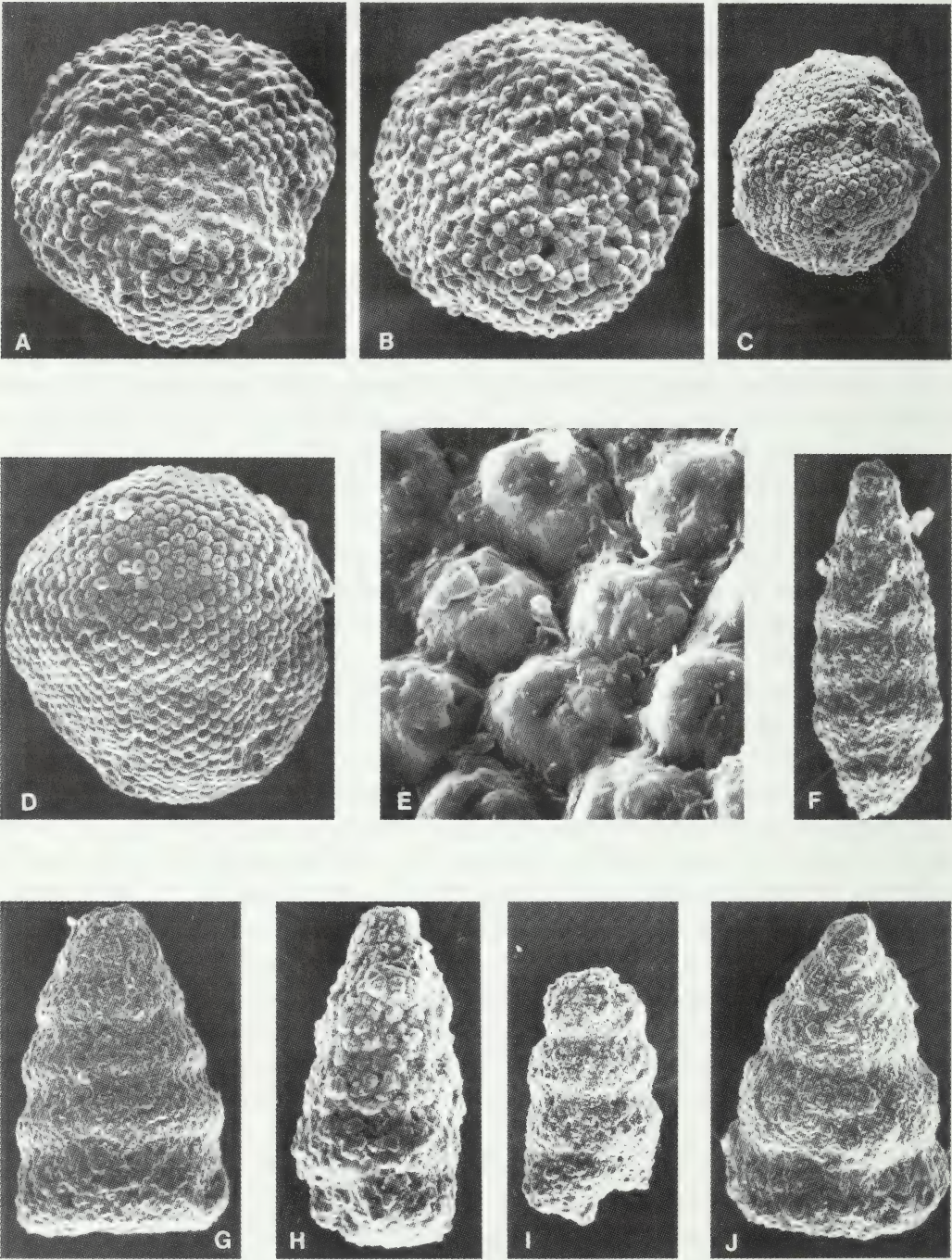


Figure 77.



*Arthropod fragments and 'shrimps' (Figs 79A–D)*

Occasional microscopic portions of arthropod claws occur. These are disarticulated, hollow elements reminiscent of crab and lobster pincers. They appear present mainly in more proximal, littoral environments. Too few examples occur in the Sundays River Formation for them to be of stratigraphic value.

In the basal Sundays River Formation cored in borehole CO 1/67, several samples (see Fig. 81) yielded microscopic 'shrimps', tiny segmented isopod-like forms. The form of the dorsal plating of these is particularly well preserved, but the nature of the numerous limbs of the ventral side has been lost.

*Echinoid spines and skeletal plates (Fig. 78C)*

Echinoid skeletal components that can be identified as such usually comprise spines and disarticulated attachment plates. The plates to which spines attach feature a prominent subglobular boss and are pentagonal in outline. The spines may be spiny, as illustrated, or ribbed rods, or spatulate at their free end.

Echinoid debris is perhaps more common in shallow marine environments of the Sundays River Formation than in deeper-water localities, but it never predominates macrofaunal assemblages. Perhaps because of the calcite crystal structure of the spines, these are invariably broken, probably as a result of differential compaction of the surrounding sediment.

*Crinoid ossicles (Figs 78E–G)*

Present in small numbers throughout the Sundays River Formation, but commonest in shallow marine environments, as in Biozone C, Late Valanginian, as well as in the marginally sited outcrops such as Zoetgeneugd Cliff.

A wide variety of skeletal ossicles, derived from the arms and possibly the stem, have been encountered. All the skeletal elements are disarticulated, and seem to be commonest in shallow marine sands, so that post-mortem disaggregation of crinoids by swell or wave activity, coupled with bacterial activity and predation by larger animals appear to be

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Fig. 77 (*see facing page*). Radiolaria. A. Microframmboidal pyrite infilling, spherical morphotype, SAM-PQ-MF1644, MV 1/79, 150 m (X), F590.  $\times 260$ . B. Microframmboidal and microcrystalline pyrite infilling, spherical morphotype, SAM-PQ-MF1645, MV 1/79, 180–190 m (X), F601.  $\times 356$ . C. Microcrystalline pyrite infilling, spherical morphotype, SAM-PQ-MF1646, CO 1/67, 915 feet (VII), F148.  $\times 154$ . D. Microframmboidal and microcrystalline pyrite infilling, spherical morphotype, SAM-PQ-MF1647, MV 1/79, 180–190 m (X), F604.  $\times 280$ . E. Close-up of pyrite surface, spherical morphotype, SAM-PQ-MF1648, MV 1/79, 180–190 m (X), F603.  $\times 2612$ . F. Microcrystalline pyrite infilling, dictyomitrid morphotype, SAM-PQ-MF1649, AL 1/69, 1 900 feet (VII), F463.  $\times 172$ . G. Microcrystalline pyrite infilling, dictyomitrid morphotype, SAM-PQ-MF1650, MV 1/79, 250–260 m (A), F628.  $\times 122$ . H. Microcrystalline pyrite infilling, dictyomitrid morphotype, SAM-PQ-MF1651, AL 1/69, 1 000 feet (III), F301.  $\times 187$ . I. Microcrystalline pyrite infilling, dictyomitrid morphotype, SAM-PQ-MF1652, AL 1/69, 790 feet (III), F259.  $\times 155$ . J. Microcrystalline pyrite infilling, dictyomitrid morphotype, SAM-PQ-MF1653, MV 1/79, 260–270 m (A), F640.  $\times 143$ .



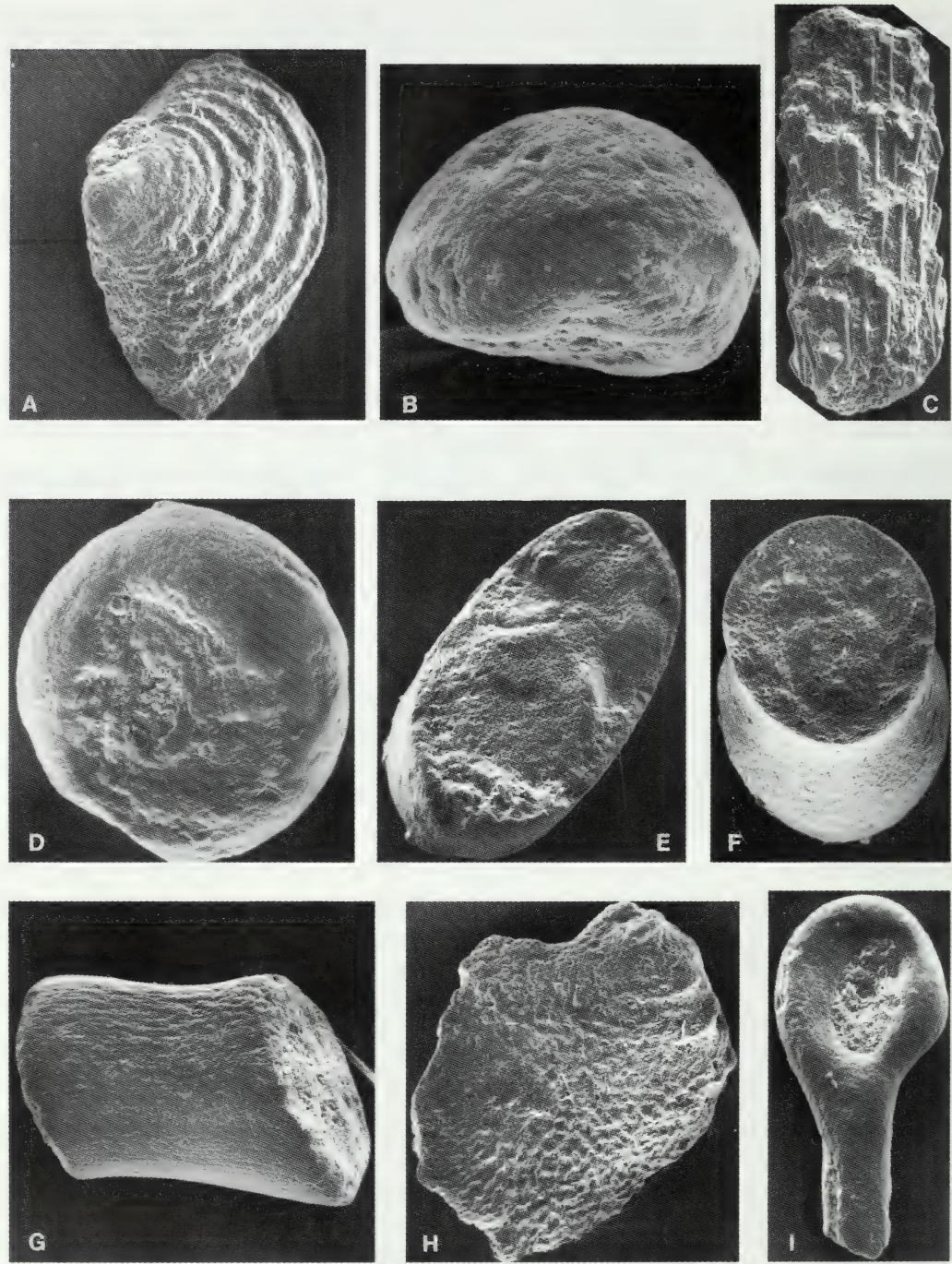


Figure 78.

responsible for their dispersal. Occasional '*Pentacrinus*'—five-pointed star ossicles—are seen, similar to that figured by McLachlan *et al.* (1976*b*, fig. 16 (no. 26)) from the Late Valanginian Brenton Formation. However, the commonest ossicles are similar to that illustrated here in Figure 78E.

*Indeterminate echinoderm debris* (Fig. 78H)

Many skeletal echinoderm elements seen in the Sundays River Formation cannot be distinguished further. Many of these are in the form of a curved plate, with an acutely angled periphery around three sides, and attachment nodes and sockets on the fourth. These may prove to be from asteroids, but present evidence is not conclusive.

*Ophiuroid ossicles* (Fig. 80B)

Again widespread throughout the sequence, and commonest in shallow marine environments. The width and length of the ossicles appears to reflect their original position within the arms of the ophiuroid. Wide, shallow and complex ossicles derive from the bases of each arm, whereas the longer, thinner, less-ornamented ones are from the free ends of each arm. All possess the distinctive vertebra-like arrangement (see also McLachlan *et al.* 1976*b*, fig. 16 (no. 24)).

*Holothurian sclerites* (Figs 78I, 80A)

These occur rarely, but widely, through the sequence. Two forms occur. Most are as illustrated (Fig. 78I) and appear to be referable to *Achistrum* (*Achistrum*) (see Hampton 1958). All examples of this form are broken at some point along the shank, and lack the presumably hook-like spear termination. Similar forms, with much the same incomplete preservation, are known from the Late Valanginian of the offshore Gamtoos Basin in particular.

At one horizon only, sieve-plate sclerites (Fig. 80A) are seen in the Sundays River Formation. These are confined to the top of the Late Hauterivian Biozone III, but occur only in the cleanly drilled AL 1/69. Based on Frizzell & Exline (1966), these would seem best referred to *Calclamnella* or a similar genus.

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Fig. 78 (*see facing page*). Miscellanea. A. *Trigonia* juvenile, SAM-PQ-MF1654, AL 1/69, 4 470 feet (A), F557.  $\times 120$ . B. Mysid statolith, SAM-PQ-MF1655, edge view, AL 1/69, 2 000 feet (VII), F477.  $\times 342$ . C. Echinoid spine, SAM-PQ-MF1657, side view, AL 1/69, 4 470 feet (A), F559.  $\times 68$ . D. Mysid statolith, SAM-PQ-MF1656, view of scalloped side, AL 1/69, 1 960 feet (VII), F472.  $\times 300$ . E. Crinoid ossicle, SAM-PQ-MF1658, terminal view, AL 1/69, 4 470 feet (A), F558.  $\times 105$ . F. Crinoid ossicle, SAM-PQ-MF1659, terminal view, AL 1/69, 4 200 feet (A), F552.  $\times 84$ . G. Crinoid ossicle, SAM-PQ-MF1660, side view, AL 1/69, 4 200 feet (A), F553.  $\times 64$ . H. ?Asteroid skeletal component, SAM-PQ-MF1661, AL 1/69, 4 200 feet (A), F554.  $\times 94$ . I. ?*Achistrum* (*Achistrum*) sp., SAM-PQ-MF1662, holothurian sclerite, AL 1/69, 4 050 feet (A), F549.  $\times 133$ .



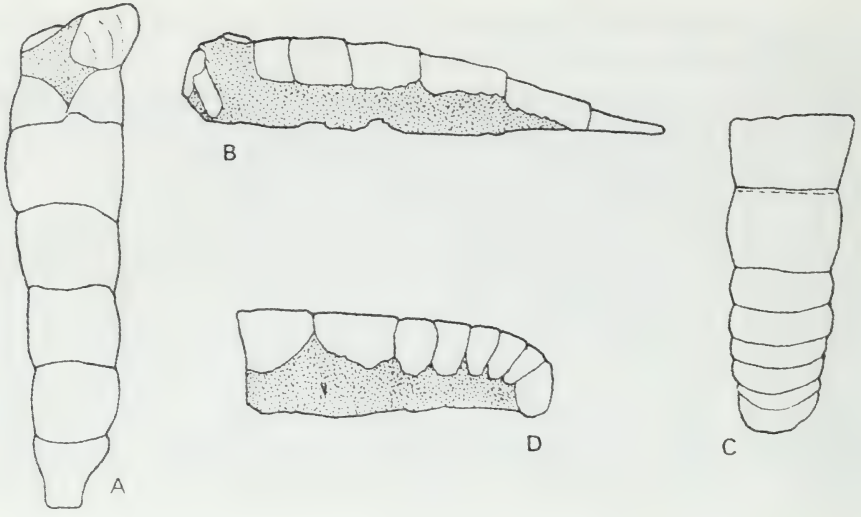


Figure 79.

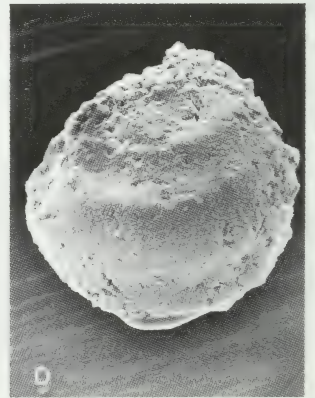
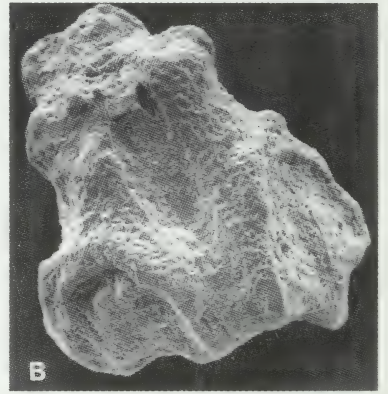
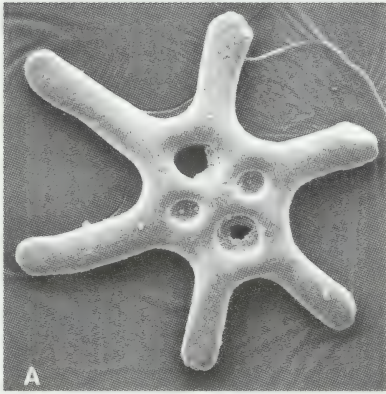


Figure 80.



*Terrestrial plant remains* (Figs 80C–D)

Beside lignite and carbonized plant fragments, which are widespread and often abundant, throughout the Sundays River Formation, megaspores, hexagonal *incertae sedis* ('hexiseds'), and one possible charophyte oogonium occur. It is generally the case that samples rich in lignite and plant debris are poor in foraminifera, with the genera *Ammobaculites* and *Haplophragmoides* usually predominant, and calcareous forms are usually rare. In samples with excessive quantities of lignite, no microfauna is preserved. In general, lignite increases in abundance towards the north of the basin, and this is also reflected by the distribution of megaspores and 'hexiseds'. Least lignite occurs in shallow-marine, wave-influenced and oxygenated environments, as at Zoetgeneugd Cliff and the Uitenhage to Graaff-Reinet Road cuttings.

Despite intensive study, we have been unable to discover the origin of the six-sided forms we have named 'hexiseds'. They are solid, composed of carbonized plant matter, and generally possess a dimpled ?attachment point at one end. The height, and the degree of taper from the wider basal to narrower upper end varies considerably, but they are always six-sided. These forms have been found in proximal environments where rapid deposition of sediment occurred. They are seen in the South African stratigraphic record from the Valanginian to the top of the Early Aptian in abundance, are less common in the Late Aptian to Cenomanian, occur rarely in the Santonian–Campanian of the Mzamba Formation, Transkei, and are widespread in Turonian to Late Santonian marginal marine rocks off the west coast of South Africa. They are clearly derived from land-plants.

Charophyte oogonia are absent in most of the Sundays River Formation, and the pyritized form illustrated (Fig. 80D) is the only possible oogonium found. Larger numbers are known from the transition beds at the top of the Kirkwood Formation along with associated non-marine ostracods, as at Mfuleni (McLachlan & McMillan 1976, fig. 7, site 15).

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Fig. 79. (*see facing page*). Two shrimp-like arthropods from the hyposaline basal Sundays River Formation. A–B. Specimen 1, SAM–PQ–MF1667, dorsal and side views, respectively, CO 1/67 3 352 feet (D).  $\times 51$ . C–D. Specimen 2, SAM–PQ–MF1668, dorsal and side views, respectively, CO 1/67 3 352 feet (D).  $\times 61$ . Ventral sides of these and all other specimens recovered from CO 1/67 core samples lack any clear detail and are infilled with cemented sediment. Specimen 1 (A–B) displays a few fragments of appendages; these are missing or not visible in all other examples studied.

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Fig. 80. (*see facing page*). Miscellanea. A. ?*Calclamnella* sp., holothurian sclerite, SAM–PQ–MF1663, AL 1/69, 790 feet (III), F224.  $\times 99$ . B. Ophiuroid ossicle, SAM–PQ–MF1664, side view, AL 1/69, 4 200 feet (A), F555.  $\times 71$ . C. Carbonized hexagonal *incertae sedis*, SAM–PQ–MF1665, 'hexised', AL 1/69, 3 900 feet (X), F545.  $\times 67$ . D. Pyritized ?charophyte oogonium, SAM–PQ–MF1666, AL 1/69, 790 feet (III), F260.  $\times 155$ .

## REPRESENTATIVE SECTIONS

Three borehole sections (Figs 81–84, *see fold-outs at back of volume*) are included as representative sections of the foraminifera and miscellaneous microfossil assemblages of the Sundays River Formation. The fully-cored section across the Kirkwood–Sundays River transition (Fig. 81A and B) in borehole CO 1/67 reveals this interval far more clearly than in any of the rotary cuttings boreholes. Cavings, and mud and drilling problems variably afflict many of the rotary boreholes, as previously described, but the sections intersected in borehole MV 1/79 through the Late Valanginian (Fig. 82), and in borehole AL 1/69 through the Late and Early Hauterivian (Figs 83 and 84, respectively), are regarded as the cleanest and most representative.

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IN MEMORIAM PETER WALTER BRENNER

SYSTEMATIC papers must conform to the International code of zoological nomenclature (particularly Articles 22 and 51).

Names of new taxa, combinations, synonyms, etc., when used for the first time, must be followed by the appropriate Latin (not English) abbreviation, e.g. gen. nov., sp. nov., comb. nov., syn. nov., etc. The name of the taxon should be followed, without intervening punctuation, by the author's(s') name(s) (not abbreviated) and the year of publication; a comma must separate author's(s') name(s) and year. The author's(s') name(s) and date must be placed in parentheses if a species or subspecies is transferred from its original genus. The name of a subsequent user of a scientific name must be separated from the scientific name by a colon.

Synonymy arrangement should be either according to chronology of names, i.e. all published scientific names by which the species previously has been designated are listed in chronological order, with all references to that name following in chronological order (see example 1), or according to chronology of bibliographic references, whereby the year is placed in front of each entry, and the synonym repeated in full for each entry (see example 2). The author should adopt one style or the other throughout a paper.

Family **Nuculanidae**  
*Nuculana (Lembulus) bicuspidata* (Gould, 1845)  
Figs 14–15A

Example 1

*Nucula (Leda) bicuspidata* Gould, 1845: 37.  
*Leda plicifera* A. Adams, 1856: 50.  
*Laeda bicuspidata* (Gould) Hanley, 1859: 118, pl. 228 (fig. 73). Sowerby, 1871, pl. 2 (fig. 8a–b).  
*Nucula largillierti* Philippi, 1861: 87.  
*Leda bicuspidata* (Gould): Nicklès, 1950: 163, fig. 301; 1955: 110. Barnard, 1964: 234, figs 8–9.

NOTE punctuation in the above example: comma separates author's name and year; semicolon separates more than one reference by the same author; full stop separates references by different authors; figures of plates are enclosed in parentheses to distinguish them from text-figures; dash, not comma, separates consecutive numbers.

Example 2

1845 *Nucula (Leda) bicuspidata* Gould, p. 37.  
1856 *Leda plicifera* A. Adams, p. 50.  
1859 *Laeda bicuspidata* (Gould) Hanley, p. 118, pl. 228 (fig. 73).  
1861 *Nucula largillierti* Philippi, p. 87.  
1871 *Laeda bicuspidata* (Gould): Sowerby, pl. 2 (fig. 8a–b).  
1950 *Leda bicuspidata* (Gould): Nicklès, p. 163, fig. 301.  
1955 *Leda bicuspidata* (Gould): Nicklès, p. 110.  
1964 *Leda bicuspidata* (Gould): Barnard, p. 234, figs 8–9.

In describing new species, one specimen must be designated as the holotype; other specimens mentioned in the original description are to be designated allotype (if applicable) and/or paratypes; additional material not regarded as paratypes should be listed separately. The complete data (registration number, depository, description of specimen, locality, collector, date) of the holotype and paratypes must be recorded, e.g.:

Holotype. SAM–A13535 in the South African Museum, Cape Town. Adult female from mid-tide region. King's Beach, Port Elizabeth (33°51'S 25°39'E), collected by A. Smith, 15 January 1973.  
Note standard form of writing South African Museum registration numbers and date.

SPECIAL HOUSE RULES

**Capital initial letters**

- (a) The Figures, Maps and Tables of the paper when referred to in the text, e.g. '... the Figure depicting *C. namacolus* ...', or '... in *C. namacolus* (Fig. 10) ....'
- (b) The prefixes of prefixed surnames in all languages, when used in the text, if not preceded by initials or full names: e.g. Du Toit, but A. L. du Toit; Von Huene, but F. von Huene
- (c) Scientific names, but not their vernacular derivatives e.g. Therocephalia, but therocephalian

**Punctuation** should be loose, omitting all not strictly necessary. Reference to the author should preferably be expressed in the third person. **Roman numerals** should be converted to arabic, except when forming part of the title of a book or article, e.g. 'Revision of the Crustacea. Part VIII. Amphipoda.' A **specific name** must not stand alone, but be preceded by the generic name or its abbreviation to initial capital letter (except at the beginning of a sentence or paragraph), provided the same generic name is used consecutively. The name of **new genus or species** should not be included in the title; it should be included in the abstract, counter to Recommendation 23 of the Code, to meet the requirements of *Biological Abstracts*.

**GENERAL.** Once referees' reports have been received by the editor, these will be discussed by the editorial committee. If the paper is considered acceptable after minor or major revision, the reports will be forwarded to the author who must then thoroughly revise in accordance with the referees' suggestions. Final acceptance of the revised manuscript will be considered by the editorial committee. In the case of major revision being necessary, the committee reserves the right to consult one or more referees regarding the revised manuscript.

I. K. McMILLI

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